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Publication of the **Transactions** of the Academy is discontinued with the issue of Volume XVI, 1898. The matter heretofore printed in the Transactions will be incorporated in the Annals.

The **Annals** (8vo), beginning with Volume XVI, will appear with new forms of typography and arrangement of matter; many changes having been made in the endeavor to facilitate the use of the volume for reference purposes. A volume of the Annals will hereafter coincide with the calendar year and will be issued in three parts. The price per volume is three dollars.

The **Memoirs** in quarto form will be published at irregular intervals. Part I of Volume I has been issued.

ANNALS

OF THE

NEW YORK ACADEMY OF SCIENCES,

VOLUME X.

I.—*The Nature and Origin of Stipules.*

BY A. A. TYLER, A.M.

Read Feb 8, 1897.

The investigation which has resulted in the preparation of this dissertation was undertaken with a view to determine the true nature and phylogenetic origin of those appendages of the bases of the petioles of leaves which are known as stipules and which are present in so large a number of the families of flowering plants.

The data have been collected from every available source; the evidences to be gathered from known geological facts have been taken into consideration, observations have been made upon the morphology and anatomy of the foliar organs in a large number of cases, and the gradual modification of leaf-forms in the annual growth of plants from simple scales to adult leaves has been carefully studied. In addition to the data so gathered, the literature dealing with the subject, relatively scanty though it is, has yielded much valuable material both by the record given of the observations of others and by the suggestion of lines of investigation.

With all this material in hand, I have endeavored to ground the theoretical consideration of the problem upon the broadest foundation possible in the present stage of the progress of science, and from a comparative study of the evidence gathered from all the various sources of information, have drawn the conclusions set forth at the close of my paper.

ANNALS N. Y. ACAD. SCI., X, April, 1897.—1.

The results of my investigations are herewith given to the public with the conviction that conclusions arrived at in the manner indicated cannot fail of interest to the reader, nor, in some degree at least, of scientific value.

COLUMBIA UNIVERSITY,
NEW YORK, Feb. 8, 1897.

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A REVIEW OF IMPORTANT LITERATURE PERTAINING TO STIPULES.

Owing to the fact that a large part of the literature pertaining to stipules is inaccessible to the majority of botanical students, scattered as it is, for the most part, in the journals of various scientific bodies, it has seemed desirable to preface the consideration of the results of my research on the question of the Nature and Origin of Stipules with a brief summary, in chronological order, of the publications having reference to the general subject of stipules. I have, however, omitted mention of their consideration in systematic works and the general allusions and definitions as they occur in most general works on the Spermatophyta together with their special consideration in individual species and groups except in the most important cases.

Stipules have not received a very large degree of attention from botanists apart from their morphology as used in classification and the publications to be considered are not very numerous. but it is thought that a review of those following will be profitable and of general interest:

Malpighi, Marcello.—Opera omnia, 22-39. 1686.

This is one of the earliest works in which stipules are treated. A considerable number are figured and described under the name of *foliola caduca.*

Linnæus, Carolus.—Philosophica Botanica, 50. 1751.

A general definition is given of stipules as scales borne at the base of the petiole. Buds are spoken of as formed by stipules, by petioles, or by rudiments of leaves.

Linnæus, Carolus.—Prælectiones in ordines naturales plantarum, 520. 1792. (Cited by Hanstein in Abhandl. Akad. Berlin, 77. 1857.)

In speaking of the whorled leaves of the Stellatæ, Linnæus says that only two of these leaves are true leaves, the remainder are stipules which have grown to the same size as the leaves.

De Candolle, Augustin P.—Theorie de la Botanique, 364. 1819.

The stipule is defined as a foliaceous appendage or accessory leaf situated at the base of certain leaves. The stipel, first so named by De Candolle, is defined as a stipule placed on the common petiole at the base of the leaflets.

De Candolle, Augustin P.—Organographie Végétale, 1 ; 334-341. 1827.

De Candolle's views as here expressed may be outlined as follows: "Stipules do not exist in any monocotyledonous plant,* nor in any dicotyledons in which the petiole has a sheathing base; among dicotyledons with leaves not sheathing, stipules are frequently wanting, especially in plants with opposite leaves. Their existence is intimately connected with the general symmetry of plants, and they occur or are wanting in all the species of a family.

"The only essential character of stipules is their lateral position at the base of the leaves, and it is not impossible that we confound under a common name objects really distinct. Their texture is, in many plants, perfectly foliaceous and in these cases they exhibit so exactly the character of leaves that we can say that they are small accessory leaves.

"In certain verticillate leaves, such as those of *Galium*, it is noticeable that the buds and young branches are not produced in the axils of all the leaves, but only of two among them which are opposite to one another. I presume that these two leaves furnished with buds are the true leaves and that the others should be considered as foliaceous stipules.

"The natural use of stipules seems to be the protection of the leaves during their development, but we must admit that in many cases their smallness or their nature or form make them inappropriate to this use, though we cannot well assign another to them, those which are foliaceous assist in the elaboration of the sap, those which are changed into spines serve for the defense of the plant.

"The tendril in the Cucurbitaceæ is perhaps a modified stipule. The ochrea of Polygonums is a prolongation of the base of the petiole into connate stipules."

In volume 2, pages 213 and 214, De Candolle says in treating of buds, "They have received particular names according as they are formed by different parts of the foliar organs, and according to the degree of their degeneration and adnation.

"1. Buds are called foliar when, the leaves being sessile, the blade itself, reduced to the form of a scale, forms the buds, as in *Daphne mezereum* L.

"2. They are called petiolar when the bases of the petioles dilated into scales form the covering of the young shoot. This occurs in petiolate leaves without stipules, as in the walnut, ash and horse-chestnut.

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* See also A. Richard. Précis de Bot., 126.

"3. Buds are stipular when the scales are formed, not by the leaves, but by the stipules which are not united with the petioles. Of these there are two sorts,—those which are formed by a great number of stipules enclosing a young shoot collectively, as in oaks, willows and elms, and those in which the stipules, free or united by their exterior margins, form a peculiar envelope for each leaf, as in *Ficus* and the magnolias.

"4. When the stipules are adherent with the petiole, these two organs united into one form the bud scales, and are named fulcral. This occurs in most of the Rosaceæ, and the scales are frequently three-lobed or three-toothed, indicating the origin of the scale formed by the petiole and the two stipules united together." Plate 21, figure 9, shows the progressive change from scales to foliage-leaves in buds that are fulcral in nature.

Bischoff, G. W.—Lehrbuch der Botanik. 177–183. 1834.

The subject is here more fully outlined than in De Candolle's Organographie. Stipules are defined as peculiar leafy expansions at the base of a free middle leaf. They are recognized as belonging to the leaf on the ground of their frequent connection with the petiole, the receiving of their vascular bundles from those of the leaf and the absence of buds from their axils. Various kinds of stipules are described and the ochrea, the ligule, the stipule in the Naiadaceæ and the ochrea of palms are included with stipular formations.

Lindley, John.—Introduction to Botany, 99. 1832.

The following statement is of interest: "The exact analogy of stipules is not well made out. I am clearly of opinion that, notwithstanding the difference in their appearance, they are really accessory leaves; because they are occasionally transformed into leaves, as in *Rosa bracteata*, because they are often indistinguishable from leaves of which they obviously perform all the functions, as in *Lathyrus*, and because there are cases in which buds develop in their axilla, as in *Salix*, a property peculiar to leaves and their modifications." The character of stipules is denied to the tendril of the Cucurbitaceæ and the tendrils of *Smilax* (p. 96) are regarded as lateral branches of the petiole.

Henry, A.—Recherches sur les bourgeons. Nova Acta Acad. Nat. 18 : 525-540. 1836. (Cited by Clos in Bull. Soc. Bot. Fr. 26 : 193. 1879.)

Henry says that he recognizes in the Betulaceæ and Cupuliferæ that the bud-scales are formed by stipules in an anamorphosed condition, and that in *Platanus* they are formed by the ochrea as he terms the basal foliar appendage in this genus.

Lestiboudois, Them.—Etudes sur l'anatomie et la physiologie des vegetaux. 1840. (Cited by himself in Bull. Soc. Bot. Fr. 4 : 746-747. 1857.)

The author states that he has shown that stipules are parts of the leaf, formed by the bundles or lateral fibers of these organs, whether they arise from bundles not yet having left the stem, from anastomosing arcades which unite the leaves as in the Stellatæ, or from the fibres of the petiole, as in the adnate stipules of Rosaceæ, or whether they are in part supplied by bundles directly from the cauline cylinder, as in *Platanus.*

In relation to the tendril in the Cucurbitaceae, he states that its bundles are derived from those which pertain to the axillary bud ; that it is therefore not a stipule, but the first foliar appendage of the axillary branch for its fibro-vascular bundles are not disposed like those of stems, but are analogous with those of petioles.

St. Hilaire, Aug.—Leçons de Botanique. 170, 1840. (Quoted by Colomb in Ann. Sci. Nat. (VII), 6 : 28. 1887.)

It is stated that the tendrils of *Smilax* are to be considered as lateral leaflets of a compound leaf.

Agardh, J. G.—Ueber die Nebenblätter der Pflanzen. (Reviewed by Fries and Wahlberg in Flora, 33 : 758-761. 1850.)

Agardh believes that, although stipules have been considered as degenerate appendages of the leaf or modifications of it, they are not at all a part of the leaf because they are formed before it, and must be considered as independent organs. The outer bud-scales and also the protective coverings of the earliest shoots of a plant are a kind of stipule-formation, leading to the conclusion that in the lower part of a shoot or the outer part of a bud the stipule-formation preponderates, and in the upper or inner parts, the leaf-formation, so that often at the lowest nodes the leaf does not develop and at the upper stipules are absent. In *Tussilago* there are special leafy shoots and the flowering shoots are provided with stipules only.

From these considerations Agardh concludes that there are two kinds of appendicular organs instead of one, namely stipules and leaves.

Astaix.—Essai sur la Théorie des stipules, thése de l'Ecole de pharmacie de Paris. 1–25. 1841. (Cited by Clos in Bull. Soc. Bot. Fr. 1 : 302. 1854.)

The conclusion is reached that the leaf is not a primitive appendage of the stipule and that the stipule is nothing more than an appendage of the leaf.

Regel, E.—Beobachtung über den Ursprung und Zweck der Stipeln. Linnæa, 17: 193–234. 1843.

Regel has studied the development of stipules in seedlings and in the growth of individual leaves. He believes, but does not feel ready to assert, that stipules are present in all Angiosperms in the earliest stages of growth. He therefore includes in stipular formations the ligule, ochrea, sheathing petiole and the supernumerary leaves of the Stellatæ. He concludes from his observations:

1. "That all the leafy organs of phanerogamic plants are divided into two entirely distinct formations, the stipular and leaf-formations.

2. "That the stipular formation arises from the base of the meristem tissue of the leafy axis, covering the summit, but always with a longitudinal cleft or one passing transversely across the apex.

3. "That perfect stipules are formed by the occurrence of two, four or more clefts in the original stipular sheath, giving rise to as many stipular leaflets.

4. "That the stipules receive their vascular bundles directly from the stem, and are usually parallel veined because of their forming originally a completely encircling sheath.

5. "That they serve always for the protection of the growing point and of the true leaves, when these are present, during their development.

6. "In all plants, organs adapted for protection belong not to the leaf-formation but to the stipule-formation.

7. "That stipules are to be regarded as a formation preceding the leaf-formation, since they appear before the leaves.

8. "That they belong primarily to a nodal ring distinct from that producing the leaves and situated either above or below it.

From these relations, as regards the leaf, interior and exterior stipules are distinguished.

9. "Interior stipules protect the formation of the following node and leaves. The leaf at the same node develops somewhat earlier or at about the same time.

10. "Exterior stipules develop before the leaf at the same node and therefore protect their own node with its leaf.

11. "As stipules are limited in the time during which they are functional, they lose their significance as soon as this purpose is fulfilled. They do not produce buds in their axils except in cases where true leaves are not developed."

The following statement (p. 227) should be noted. "In some species of *Thalictrum* the membrane rising above the inner margin of the base of the petiole is the analogue of the ligule."

Kirschleger, F.—Flora, 28 : 615. 1845.

The tendril of Cucurbitaceæ is regarded as a normal stipular formation.

Mercklin, C. E.—Entwicklungsgeschicte der Blattgestalten. 1846. (Translated into the French in Ann. Sci. Nat. (III), 6 : 215–246. 1846.)

The statements of Mercklin are contrary to those of Regel. He says, "In all cases the stipules of the developing leaf appear as portions of the lamina; it is only later, during the development and elongation of the petiole, that they become sufficiently separated to be considered as distinct organs. In all simple leaves the stipules never appear at the same time with the first rudiments of the lamina; they develop only with the inferior parts of the lamina including the petiole."

"From my observations of stipules I conclude that in common with the leaflets they owe their origin to the common petiole and are formed later than the leaflets."

Krause, G.—Einige Bemerke über den Blumenbau der Fumariaceæ und Cruciferæ. B. Cruciferæ. Bot. Zeit. 4 : 137–150. 1846.

Stipules in the Cruciferæ are considered (pp. 142–145) and the homology with stipules of the so-called glands at the base of the leaves is established by a careful series of observations upon their development. The glands of the bracts and floral organs are also included.*

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* See also Duchartre, Rev. Bot. 2 : 208. 1845-7 and Norman, Quelques Observ. de Morph. Veg. 1857.

Jussieu, Adrien.—Cours d'Histoire Naturelle: Botanique. 108-111. 1852.

Speaking of the leaf-sheath, Jussieu says that "sometimes the vascular bundles converge little by little, and there is a gradual transition from the sheath to the petiole; sometimes the marginal bundles stop after a course varying in length, or are prolonged in another plane than that of the petiole, and then there is a clear distinction of petiole and sheath. Often, however, the parenchyma does not unite the lateral bundles to the central ones which continue in the petiole, and this is the probable origin of many stipules."

Trécul, A.—Sur la Formation des Feuilles. Ann. Sci. Nat. (III), 20: 288-299. 1853.

The usual classification of stipules is given with the addition of extra-foliar stipules to include those of *Nelumbium.* The author says, "In all adnate stipules that I have seen, they do not envelop the leaf to which they belong, but that which comes next after them, and their own leaf is protected by the stipules of the leaf preceding. Under these circumstances the stipules play the same rôle as the sheath, from which they differ very little. We see thus clearly that there is the closest analogy between the formation of adnate stipules and that of a sheath; the analogy is such that it is impossible to distinguish between them in principle." All the forms of stipules, the ochrea, the tendrils of *Smilax* and the ligule of grasses are classed together.

Among the conclusions those relating to stipules are as follows: In basifugal leaf-formation all the parts are formed from below upward, the stipules first of all. In leaves with basipetal formation, the stipules have their origin earlier than the lower parts of the blade and sometimes even before the upper.

Trécul, A.—Vegetation du Nelumbium codophyllum. Ann. Sci. Nat. (IV), 1: 291-298. 1854.

In the seedling of this plant the leaves are in two ranks on the upper and lower sides of the rhizome and each of them is provided with an axillary stipule. In its later stages the leaves of the lower rank are aborted with the exception of the stipule of every second one and in the upper rank every second leaf is represented by the stipule only. The internodes above the stipules which stand alone remain undeveloped so that three stipules are associated with each leaf, one axillary and two extra-axillary.

One of these last is on the upper side of the rhizome external to the leaf, the other on the lower side.

This paper was presented before the Botanical Society of France, May 24, 1854. M. Ad. Brongniart took part in the discussion which followed. He agreed with Trécul in his conclusions and closed with the statement that "this arrangement recalls that of certain buds in which the scales result from the stipules of leaves of which the petiole and blade are alike aborted." M. F. J. Lestiboudois remarked that "to decide whether stipules are an integral part of the leaf, it is necessary to study them anatomically. In other plants the same fibro-vascular bundles are distributed to the leaf and stipules. Stipules should therefore be regarded as appendages of the leaf."

Clos, D.—Considerations sur la Nature du prétendu Calicule ou involucre des Malvacées. Bull. Soc. Bot. Fr. 1: 289–303. 1854.

The stipular nature of the parts of the involucre or exterior calyx in the Malvaceæ is asserted contrary to the views of Aug. St. Hilaire (Leçons de Bot. 372. 1840) and the term *stipulium* is suggested as applicable to it.

Clos, D.—Du Stipulium chez les Géraniacées, les Légumeneuses et les Rosacées. Bull. Soc. Bot. Fr. 2: 4. 1855.

The term *stipulium* is applied to the exterior calyx of the Malvaceæ and the involucre of the umbel of some Geraniaceæ. In the Cistaceæ the bractlets of the calyx are wanting in exstipulate species.* In many of the Leguminosæ and Rosaceæ the bracts are evidently formed by stipules.

Clos, D.—La Vrille des Cucurbitacées, Organe de Dédoublement de la Feuille. Bull. Soc. Bot. Fr. 3: 545–548. 1856.

The different theories regarding the tendril in the Cucurbitaceæ are briefly stated. They have been considered to be roots; abortive peduncles by Tassi; stipules by De Candolle, Stoks and Aug. St. Hilaire; leaves by Gasparini, Seringe and Braun; degenerate branches by Meneghini; superfluous branches by Link; terminal branches of the axis as in Vitaceæ by Fabre; partly leaf, partly branch by Naudin. Clos concludes that the tendril arises by a division of the leaf, three fibrovascular bundles entering the leaf when there is no tendril and two when the tendril is present and receives the third bundle.

* See also Aug. St. Hilaire. Leçons de Bot. 326 and 371. 1840.

Clos, D.—Les Vrilles des Smilax ni Folioles ni Stipules. Bull. Soc. Bot. Fr. 4: 984–987. 1857.

A summary is given of the literature pertaining to the tendrils of *Smilax.* They are considered as representing two lateral leaflets of a compound leaf by von Mohl (Ueber den Bau und das Winden der Ranken und Schlingpflanzen, 41, 1827), Lindley (Introd. to Botany, Ed. 2, 118, 1835), Link (Elem. Phil. Bot. Ed. 2, 1 : 478, 1837), St. Hilaire (Leçons de Bot. 170 and 854, 1840), Le Maout (Atlas de Bot. 23, 1846) and Duchartre (Art. vrille in Dict. Univ. Hist. Nat.).

Mirbel (Élém. de Physiol. et de Bot., 2: 680, 1815), Treviranus (Physiol. der Gewachse. 2: 138, 1838), Seringe (Élém. de Bot. 175, 1841), De Candolle (Theorie Élément. Ed. 3, 321, 1844), Trècul (Ann. Sci. Nat. (III), 20: 295, 1854) and Lestiboudois (Bull. Soc. Bot. Fr. 4: 745, 1857), believe these organs to be stipular tendrils. It is the opinion of Clos that they are neither leaflets nor stipules, but a double lateral prolongation of the cellulo-vascular elements of the petiole.

Rossman, J.—Beiträge zur Kentniss der Phyllomorphose. 1857. (Cited by Clos in Bull. Soc. Bot. Fr. 26: 192. 1879.)

Rossman considers the problem of the nature of stipules, and from a study of bud-scales arrived at his conclusions. He figures the passage from bud-scales to leaves in *Ribes sanguineum* Pursh, *Prunus Padus* L., *Spiræa sorbifolia* L., etc. He notes the presence in the bud-scales of three median veins, separated at the base and joining one another at the apex, where the petiole will originate. The lateral parts of the scale outside of these three nerves he believes to represent the stipules which show themselves at the appearance of the blade in two little points at the apex.

Hanstein, J.—Uebergürtleformige Gefässstrang-Verbindung in Stengleknoten dicotyler Gewächse. Abhandl. der Akademie der Wissenschaften zu Berlin, 1857 : 77–98. 1858.

The vascular nodal girdle of the Stellatæ is treated of at length. It is shown that from this girdle arise the bundles that supply those leaves of the whorl which are really stipules, and in some cases also the veins of the lateral parts of the true leaves. Similar nodal girdles are shown to exist in other families of plants, notably in *Sambucus*, *Valeriana*, *Verbena*, *Dipsacus*, *Scabiosa*, *Dahlia* and *Silphium*. In *Sambucus Ebulus* L. the girdle sends off vascular branches to true stipules. In the majority of other cases if branches arise they enter the margins of the petioles or the interfoliar portions of connate leaves. In *Platanus* and *Liriodendron* with alternate leaves, each of which receives seven vascular bundles, a similar girdle is shown to pass around the stem posterior to the leaf, and is there joined by another small leaf-trace bundle. From this girdle arise a part of the stipular veins, the others being branches of the sixth and seventh leaf-trace bundles.

Clos, D.—Sépales Stipulaires. Bull. Soc. Bot. Fr. 6: 580–589. 1859.

It is argued from the similarity of the sepals to the divisions of the involucre (stipulium) and also to the stipules of the fully developed foliage leaves which is frequently observed, that they represent stipules. This is held to be true in many Geraniaceæ, Malvaceæ, Begoniaceæ and Cistaceæ. In concluding Clos adds the theoretical consideration that "whether or not stipules are admitted to be organs different from the leaf, analogy seems to demand that in some cases at least they should participate in some degree in floral formation."

Cosson, E.—Note sur la Stipule et la Préfeuille dans le Genre Potamogeton. Bull. Soc. Bot. Fr 7: 715–720. 1860.

"The stipule in *Potamogeton* is very closely like the first leaf of one of the branches. It is homologous with the ligule of the Gramineæ and Cyperaceæ and is constituted by a single organ, not by two united by their margins."

Eichler, A. W.—Zur Entwicklungsgeschichte des Blattes. 22–31, 1861 (Cited by Martin Franke in Bot. Zeit. 54 :45, 1896.)

Stipules are said to arise without exception as a product of the leaf base of the primordial leaf. This mode of origin of the stipules is their chief characteristic. Their form, their more or less foliaceous condition and their persistence are secondary.

In individual leaf development in the Stellatæ, the whorl originates in a uniform ring about the growing point. Then arise two opposite prominences in the ring. These develop into the true leaves. After them appear two smaller prominences on each side of the stem between the first. These are the stipules. According to the species they develop separately, forming six-leaved whorls, or grow together giving origin to four-leaved whorls.*

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*With this view Göbel agrees (Schenk's Handbuch der Botanik 3 : 230. 1884), except that he does not distinguish the time of appearance of the different parts of the whorl.

Where a larger number of leaves occurs, an additional prominence for each arises between the original stipular prominences.*

Cauvet, D.—Probabilité de la Presence des Stipules dans quelques Monocotyedones. Bull. Soc. Bot. Fr. 12 : 241. 1865.

A number of cases are considered and the conclusion drawn that very probably some Monocotyledones are provided with stipules, but the difference in their form and position has caused them to be considered as another kind of organ.

Meehan, Thomas.—On the Stipules of Magnolia and Liriodendron. Proc. Acad. Nat. Sci. Phila. 114–116. 1870.

Mr. Meehan argues for the origin of the stipules of *Magnolia* as lobes of the lamina similar to the auricles which occur in *M. Fraseri* Walt. by a union of the auricles with the upper surface of the petiole, and a subsequent adnation of their margins and separation from the lamina. He says, " It is scarcely possible to avoid the suspicion that the stipules of *Magnolia* are not formed like the stipules of most plants which are perhaps leaf portions which have never been well developed, but rather are the tolerably well developed side pinnules of a trifoliate or deeply auricled leaf."

Speaking of observations upon the flowers of *M. fuscata* Andr., of East India, the following interesting statement is made : " This observation confirms the views of some botanists as I have learned from Professor Asa Gray, that it is by metamorphosis of the petiolar and stipular parts, rather than by modifications of the leaf-blade, that petals are formed."

Duval-Jouve, J.—Sur quelques tissues de Joncées, etc. Bull. Soc. Bot. Fr. 18 : 231–239. 1871.

The presence of the ligule in the Juncaceæ is treated of. To quote the author, " If in certain species the ligule is so reduced that it appears to be lacking between the separated auricles at the apex of the sheath, in most others these auricles are united by a true ligule, as pronounced as that of grasses, either entire or cleft at the middle."

Dutaily, G.—Sur les variations de structure de la ligule des Graminées. Bull. de la Soc. Linnéene, 170. 1878.

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*F. Pax (Allgemeine Morph. der Pflanzen, 100. 1890) says, when there are more than six parts to the whorl, the additional parts must have their origin in a division of the blades of the stipules.

It is argued from the presence of a median vein in the ligule of some of the grasses in which this organ is supplied with vascular support that it cannot be formed of two stipules grown together.

Hilburg, C.—Dissertation über den Bau und die Function der Nebenblätter. (Reviewed by F. Hildebrand in Flora, (II), 36 : 161–167. 1878.)

The general neglect of the subject of stipules and the timeliness of this dissertation is referred to by the reviewer.

The functions of stipules as protecting organs are discussed. They are considered under the heads of (1) those protecting the buds in winter, (2) those protecting the growing parts in the spring, (3) those which serve as protection against insects and other animals, (4) those which serve as well the function of assimilation.

The adaptation of most stipules in their form and manner of growth to the special function they are intended to fulfill and the apparent lack of function in others is remarked upon.

Clos, D.—Des Stipules et de leur rôle à l'infloresence et dans la Fleur. Mem. Acad. Sci. Toulouse, (VII), 10: 201–317. 1878.

This paper is the first part of an extended consideration of the subject of stipules. It deals with their occurrence in the families of plants and their importance in classification on account of the great variety of their characteristics.

Clos, D.—De la part des Stipules a l'infloresence et dans la Fleur. Comptes Rendus, 87: 305–306. 1878.

The stipular nature of the sepals in *Geranium*, *Helianthemum*, *Begonia*, *Oxalis*, *Alchimilla*, *Viola* and many other genera in different families is maintained.

Dixon, Alex.—On the stipules of *Spergularia marina*. Journal of Botany (Trimen), 7: 316. 1878.

Attention is called to the anomalous connation of the stipules of *Spergularia marina* Griseb. exterior to the petioles of the opposite leaves.

Clos, D.—Des Stipules considérées au point de vue morphologique. Bull. Soc. Bot. Fr. 26: 151–155. 1879.

Under this title a summary of the opinions of botanical authorities as to the true nature of stipules is given and the different theories are briefly discussed.

Various leaves have been considered as stipules, for example the primary leaves of *Asparagus* (Dutrochet), the first leaves of the branches of *Verbena aphylla* Gill & Hook. (Hooker, Bot. Misc. 1: 116. 1830) and of the Piperaceæ (C. DeCandolle, Mém. sur les Piper. 18–19, 1866), and the first two leaves of the axillary buds of many Solanaceæ.

The appendages sometimes accompanying the leaf in some Convolvulaceæ, as *Ipomea stipulacea* Sweet., have been considered as stipules (Jacquin. Pl. Hort. Schoenbr. Descr. et Ic. 2: 39. 1797).

Many have regarded stipules as leaflets, as for example in *Vibernum* (Baillon, Adans. 1: 372. 1860), and the lower leaflets in many plants have been taken for stipules, as in *Cobœa scandens* Cav. (Blume. Rumphia 3 : 142. 1837), and *Lotus tetraphyllus* Murr. (Linnæus, Trinius, E. Meyer, Fischer.)

In 1844 Wydler declared that stipules belong to the sheath and cites examples of transition between the two kinds of organs in the Rosaceæ, Polygonaceæ, Leguminosæ, etc. Stipules, in connection with the sheath have been ascribed to *Ranunculus*, *Isopyrum* and *Thalictrum* by Lloyd (Fl. de l'Ouest de Fr. Ed. 2, 1868), to *Caltha* by Wydler, Kützing (Grundz. der phil. Bot. 684, 1851–52) and Hooker. They have been recognized in the scales of the stems of the Aroids.

The so-called " decurrences " of leaves do not differ anatomically from stipules and are to be considered as identical with them, as for example in *Crotalaria*.

The tendril of the Cucurbitaceæ has been regarded as a stipule by Seringe (Mém. Soc. Hist. Nat. Genèv. 3 : 1–31. 1825), De Candolle (Organ. Veg. 1 : 336. 1827), Kirschleger (Flora, 28 : 615. 1845), Stoks (Ann. Nat. Hist. 1846), Payer (Elém. de Bot. 53. 1857–58), Parlatore, etc. Those of *Smilax* have been so considered by Cauvet (Bull. Soc. Bot. Fr. 12: 241. 1865), but are looked on by Clos as " simple prolongations of the fibro-vascular bundles of the petiole without morphological signification."

The spines of the orange are considered as stipules by Du Petit-Thouars (Cours de Phytol. 47. 1820). Clos regards them as branches and those of *Amaranthus spinosus* L. as leaves, though they are considered stipular by Lamarck (Encyc. Meth. 2 : 118. 1786). *Ribes* shows stipular spines in some species. The spines of *Xanthium spinosum* L. mentioned by Sachs as occupying the place of stipules, Clos regards as representing pistillate flowers. He looks with disfavor on the doctrine that the glands at the base of the leaves in Resedaceæ, Cruciferæ, *Epilobium*, *Lyth-*

rum and some Euphorbiaceæ and Balsaminaceæ as well as the axillary hairs in some Portulacaceæ are stipules.

Clos, D.—Indépendance, developpement, anomalies des stipules; Bourgeons a écailles stipulaires. Bull. Soc. Bot. Fr. 26 : 189-193. 1879.

Stipules have been regarded as appendages of the leaf by Du Petit-Thouars (Cours de Phytol. 46, 1820), Aug. St. Hilaire (Leçons de Bot. 189, 1840), G. St. Pierre and F. J. Lestiboudois.

Clos agrees with Agardh in considering stipules as independent organs. giving as his reason that frequently in the Rosaceæ, Leguminosæ, Malvaceæ, Geraniaceæ, etc., the stipules persist alone, the leaves having completely disappeared, whether in the infloresence or at the base of stems and branches.

Under the head of the development of stipules the conflicting opinions of Mercklin and Trécul as to their time of appearance in relation to that of the leaf-blade is referred to. Agreement with Trécul is indicated and the evidence is not considered sufficient as a basis for the theory of the autonomy of stipules on the ground that they appear before the leaf-blade.

In consideration of stipular bud-scales reference is made to their recognition by Linnæus (Phil. Bot. Ed. 3, 52. 1790), Adanson (Familles des Pl. 246, 1763), De Candolle (Ann. Sci. Nat. (III), 5 : 321, 1846)* and Lindley (Veg. Kingdom, 283, 1846).

Göbel, K.—Beiträge zur Morphologie und Physiologie des Blattes. Pt. I. Die Niederblätter. Bot. Zeit. 38: 753, etc.—845. 1880.

This extended treatise deals with bud-scales and the scales of subterranean parts of plants and their homologies with leaves. Speaking of the primordial leaf Göbel says, "it is divided into two parts, a stationary zone which takes no farther part in the leaf-formation and a part out of which the lamina is developed." He calls these parts respectively the leaf-base and upper-leaf and states that the petiole arises after the formation of the blade and is inserted between the two parts.

Bud-scales are regarded as modified foliage-leaves and divided into those formed from the blade (*Syringa*), those formed by the leaf-base (*Æsculus*, *Prunus*), and those consisting of stipules (*Liriodendron*, *Quercus*). In *Prunus*, etc., the formation of the bud-scales by the union of petiole and stipules is denied on the ground that the continuous separate development of the petiole and stipules can be followed.

* See also Org. Veg. 2: 213. 1827.

The scales of rhizomes are divided into those formed by a development of the leaf-base (*Dentaria*, *Chrysosplenium*) and those formed by a modification of the upper-leaf (Labiatæ, Onagraceæ).

Colomb, G.—Note sur l'ochrea des Polygonées. Bull. Soc. Bot. Fr. 33: 506–507, 1886.

"The ochrea of the Polygonums is a complex organ formed of two parts: one opposite the leaf, the leaf-sheath, the other in its axil and detached from the petiole. This is a ligule." "Practically the same conditions prevail in the Gramineæ as in *Polygonum* with the difference that in the former the sheath proper is greatly developed and little prolonged beyond the insertion of the blade, while in the latter, the sheath proper remains short and is much prolonged above the petiole. By union with the ligule it forms an ochrea. So considered the ochrea is not peculiar to the Polygonaceæ. It is found also in *Ficus* and *Magnolia*, establishing the transition between the ochrea and stipules properly so called.

Vuillemin, P.—Apropos d'une recent communication de M. Colomb. Bull. Soc. Bot. Fr. 34: 141–142. 1887.

Commenting on the preceding paper, the author says that the leaf is primitively unifasciculate. The concrescence of a verticil of elementary leaves, such as occurs in the fossil *Asterophyllites*, gave a sheath analogous to that of *Equisetum;* the bundle of one of these elementary leaves becoming predominant and functioning as a midvein gave rise to an aggregate leaf, the first stage of a high differentiation. In this way the origin of the leaf-blade in *Polygonum*, *Platanus*, etc. is explained, while the ochrea, the homologue of the sheath of *Equisetum*, remains as a vestige of the primordial state.

Kronfeld, M.—Ueber die Beziehung der Nebenblätter zu ihrem Hauptblatte. Verhand. der Kais.-Konig. Zool.-Bot. Gesellschaft Wien. 37. Abhandl. 69–79. 1887.

The author has made investigations experimenting upon a large number of plants, by the removal of the lamina of the leaves at the earliest possible stage of development, in order to observe the effect upon the development of the stipules and so determine their physiological relation to the leaf-blade. Only in exceptional cases was the ultimate size of the stipules increased, and those where the stipules were normally foliaceous.

Colomb, G.—Recherches sur les stipules. Ann. Sci. Nat. (VII), 6 : 1-76. 1887.

This paper is the result of an exhaustive anatomical study of stipules and their homologues. The results obtained are of great interest and value. They are admirably summed up at the close of the paper as follows :

" When a leaf is sheathing, the sheath may be prolonged in a ligule situated above the point of insertion of the blade upon the sheath.

" In this organ three regions may be recognized :

" 1. The lateral regions into which the marginal bundles of the sheath are merely prolonged. These regions naturally do not exist if all the bundles of the sheath enter into the leaf.

" 2. The stipular regions, the bundles of which arise from a doubling of the last bundle of the sheath entering into the leaf.

" 3. The axillary region, which unites the two stipular regions, a lamina, usually of parenchyma, but which may receive bundles arising from the internal doubling of those bundles of the sheath which become petiolar.

" The sheath may be reduced even to complete disappearance without a consequent disappearance of the ligule.

" 1. If the ligule is complete with its three regions, I give it the name of an axillary ligule.

" 2. If the stipular and axillary regions only persist, the sheathing regions having disappeared, we have an axillary stipule.

" 3. If finally the axillary region divides into two halves, right and left (which would not be remarkable, considering its purely parenchymatous nature), the stipular regions exist alone at the base of the petiole, and we have then stipules properly so-called.

" Stipules and the ligule are then organs of the same nature, between which it is possible to find all forms of intergradation, the stipule being a portion of the axillary ligule.

" When, finally, the manner of origin of the bundles of the stipule is studied, we arrive at the following definition of the organ: An appendage inserted on the stem, at the base of the leaf, all the bundles of which arise exclusively from the corresponding foliar bundles."

Each of the tendrils of a leaf of *Smilax* is characterized as a demi-ligule, the " stipule " of *Potamogeton* as a ligule identical with that of grasses, the ochrea of *Polygonum* and *Platanus* as axillary stipules, the stipules of *Ficus elastica* Roxb. and *Magnolia grandiflora* L. as axillary ligules.

Ward, L. F.—The Paleontologic History of the Genus Platanus. Proc. U. S. Nat. Mus. 11: 39–42. 1888.

Professor Ward says (p. 41) in speaking of the fossil leaves of *Platanus basilobata* Ward, of the Yellowstone valley, that some of those found had "a remarkable expansion at the base of the blade, projecting backward on the leaf-stalk and having two to five lobes or points.

"These expansions are to be interpreted as evidence that the leaves all belong to *Platanus* or to some extinct ancestral type of the genus, since something quite analagous to them is found in our American plane-tree. The ordinary leaves of this tree are, it is true, destitute of basilar expansions, but those on young shoots, and sometimes those on the lower or non-fruit-bearing branches of trees exhibit this peculiarity.

"In place of this backward expansion of the blade many sycamore leaves have an appendage similar in shape at the base of the leaf-stalk, as though the once basilar appendage had been separated from the blade and crowded down the petiole to its point of insertion." This is shown in a short-petioled, wedge-shaped leaf from a young shoot of *Platanus* corresponding to the fossil form of *Platanus appendiculata* Lesq. from the auriferous gravels of California. The indication is that "the constriction seen in the fossil forms between the blade of the leaf and the appendage would seem to represent the beginning of this process of detachment."

Ward, L. F.—Origin of the Plane-Trees. Am. Nat. 24: 797-810. 1890.

The same cases as those in the preceding paper are discussed, the appendages in *Platanus appendiculata* Lesq. being described as stipular, while those of *P. nobilis* Newb. and *P. basilobata* Ward are not so considered.

Lubbock, Sir John.—On Stipules, their Form and Function. Jour. Linn. Soc. Lond. 28: 217–243. 1890.

"The primary function of stipules seems to be to protect the bud. In other species, however, they serve as accessory or deputy leaves. Their protective function is confirmed by the fact of their early fall. Some are more persistent than the leaves and protect the leaves of the following year.

"When stipules are present [in *Helianthemum*] the petiole is always very narrow, semiterete, and tapered to the base. Where they are absent the leaf is often sessile and, whether or not, its base is always dilated and concave on the inner face, completely enclosing the bud up to a certain stage of its development."

The presence of stipules in the lower imperfect leaves of *Ailanthus glandulosa* Desf. is noticed, though the family of the Simarubiaceæ has been described as exstipulate. In *Ribes sanguineum* Pursh. the bud-scales are described as consisting of the dilated base of the petiole, the lamina being represented by a small black point. "One or two succeeding leaves bear a small lamina sessile on the sheath, which is wholly adnate to the thin dilated base of the petiole and membranous, especially outside of the three vascular bundles. The next one or two have a well-developed lamina, and the sheaths partly separated from the petiole and corresponding to stipules. Farther up the stipular sheaths are shorter and wholly adnate to the petiole."

The form and function of the stipules in a large number of species are described.

Lesquereux, L.—U. S. Geol. Surv., Monog. No. 117: Geology of the Dakota Group. 1892.

Well-developed stipules of a species of *Betulites* from Kansas are described (p. 65) as having been found in their original connection with the leaf, and the discovery of leaves of a *Cratægus* with large undoubted stipules, from the Devonian of Wyoming is mentioned (p. 254). Speaking of a leaf of *Aspidiophyllum* (p. 232). Professor Lesquereux says, "the basilar appendage or pelta is like a primordial form of stipules, as in *Platanus basilobata* Ward of the Laramie group of Wyoming, *P. appendiculata* Lesq. of the auriferous gravels of California and definitively in *P. occidentalis* L. of the living flora."

Henslow, Rev. George.—On a Theoretical Origin of Endogens from Exogens. Jour. Linn. Soc. Lond. 29: 485-528. 1893.

The absence of vascular bundles in certain stipules is noted (p. 494).

Hollick, Arthur.—Wing-like Appendages on the Petioles of *Liriophyllum populoides* Lesq. and *Liriodendron alatum* Newb. Bull. Torr. Bot. Club, 21: 467-471. 1894.

These peculiar wing-like appendages are described and figured. Their similarity to the appendages in fossil species of *Platanus* as described by Professors Lesquereux and Ward is mentioned, and the probability suggested that we have here an explanation of the origin of the stipules of *Liriodendron Tulipifera* L. in the same manner as that indicated for those of *Platanus occidentalis* L. by Professor Ward. The presence of an unwinged portion of the petiole next to the blade in what is evidently the mature form of the leaves of *Liriophyllum*, and its absence in the immature ones is mentioned as tending to confirm the theory.

In commenting on this paper, the *Botanical Gazette* (19: 515, 1894) says, "The phyllopodium is to be regarded as an axis which has a tendency to develop wing-like appendages at any portion, notably, of course, in the epipodium. If stipules are branches of the hypopodium their origin has simply to do with the branching of that part of the phyllopodium, without any reference to the method of winging found in other regions."

Lubbock, Sir John.—On Stipules, their Form and Function. Pt. II. Jour. Linn. Soc. Lond. 30 : 463–532. 1894.

This paper is a continuation of the author's former publication.

The presence of stipels in *Sambucus Ebulus* L. is noticed. The membranous protective margins of the sheath in *Thalictrum aquilegifolium* L. and the "membranous stipular processes at each trifurcation of the lamina" are mentioned, the latter "appearing to differ somewhat in their origin from the primary sheath." In treating of *Ranunculus aquatilus* L., the author says, "The terminal bud is enclosed by the stipules of the two uppermost expanded leaves. The developing leaves push their way out at the apex of the stipular sheath. Similarity of conditions have therefore developed in the aquatic Ranunculaceæ, an arrangement very similar to that of the Potamogetons."

The following remarks are of particular interest: "In *Magnolia glauca* L. the winter bud is covered by a pair of connate stipules adnate to a petiole that is less than half their length. Succeeding leaves are perfect, and the stipules are two or three times as long as the petiole, the free portions being connate by both edges, like a candle extinguisher, over the bud, so that the leaf appears to spring from the back. As they are adnate to the petiole, there is some reason to assume that the stipules once formed a sheath pure and simple to the leaf of some ancestral form."

Franke, Martin.—Berträge Zur Morphologie und Entwicklungsgeschichte der Stellaten. Bot. Zeit., 54: 33–60. 1896.

In the part of this paper which treats of the development of the leaf-whorl the author agrees with Eichler that the stipules originate later than the principal leaves. But he says that in the species having four-leaved whorls never more than four prominences arise to develop into the parts of the whorl, and that if the parts number six or more, there is a distinct prominence for each. In the last case the supernumerary stipules first make their appearance in the course of development of the whorl a little later than the first pair of stipules.

Hollick, Arthur.—Appendages to the Petioles of Liriodendra. Bull. Torr. Bot. Club, 23: 249. 1896.

The author, referring to his former paper, describes and figures some abnormal leaves of *Liriodendron* collected from saplings, seedlings and new shoots from old stumps. One in particular of these leaves is of interest on account of its similarity to the fossil leaves of *Liriophyllum populoides* Lesq. both in the form of the lamina and especially in having a short petiole with broadly winged margins which extend from the base of the petiole and connect with the base of the leaf-blade.

The question is put whether in this case we have "stipules adnate to the petiole and leaf-blade, or portions of the leaf-blade which are acting the part of stipular appendages."

Such, in brief, is the import of what has been written on the subject of stipules, so far as I have been able to learn. The results of my own observations are not at variance to any very considerable degree with the opinions of most of the botanists who have studied the subject carefully, as will appear from the following exposition of my investigations and the conclusions at which I have arrived. To these I shall pass at once, deeming unnecessary farther comment on previous writings, except such as the statement of my results may imply.

THE NATURE AND ORIGIN OF STIPULES.

Though it is not part of the purpose of this paper to discuss the problem of the phylogeny of the plant world, it is nevertheless necessary in order to define our field of inquiry to make a brief statement concerning the probable relationship of the higher forms, namely of those in which foliar organs are developed, including in the widest interpretation the Characeæ, Bryophyta, Pteridophyta and Spermatophyta.

As, in the Characeæ and Bryophyta, the plant body represents the gametophyte stage of development, there can be no homology of the leaves of these plants with those of the Pteridophyta and Spermatophyta in which the plant body is the sporophyte. For this reason the so-called stipules of the Charas, together with the basal lobes or saclike and straplike appendages of the leaves of many Hepaticæ need not be taken into consideration.

Accepting the general theory of evolution in nature, we must admit that the origin of all the higher plants is algal, but just what the relationship of the Pteridophyta to the Spermatophyta may be is still an open question. The same is true in greater or less degree of the affinity of the Monocotyledones, Dicotyledones and Gymnospermæ in the latter group.

This question of relationship is of considerable importance in connection with the problem before us as determining the homology of the foliar appendages in the several groups. The evidence in support of the doctrine of the common origin of all the Angiospermæ is particularly strong and may be considered as conclusive. But the relationship of the Gymnospermæ to the Angiospermæ is more remote, and that of the Pteridophyta still more so-and, though there are many points of resemblance, the similar characters may be cases of parallel development rather than indications of a common origin. It is my present opinion, however, that the Gymnospermæ sprang from some generalized hetero, sporous Pteridophyte,* that the early Angiospermæ were differentiated from related forms, and that therefore, the foliar organs in the three groups may be considered as homologous. But this homology can apply to the leaves of Pteridophytes in a very general way only, namely, to such undifferentiated forms of leaves as the ancestors which gave rise to the early Gymnospermæ and Angiospermæ may be supposed to have had. While, therefore, the foliar organs in the three classes are to be considered homologous in their origin, they cannot be so considered in their differentiation and the evolution of leaf-forms in the Pteridophyta and Gymnospermæ, though analogous in many points to their evolution among the Angiospermæ, should be regarded as independent. We may then consider the "stipule" of the Ophioglossaceæ, Marrattiaceae and Osmundaceæ and the "ligule" of *Selaginella* and *Isoetes* as special developments and as properly placed in a separate category from the appendages bearing these names among the Angiospermæ. The Gymnospermæ present nothing to represent either stipule or ligule and we have left for our special consideration the ligule, stipule and their homologues as they occur in the various groups of the Angiospermæ only.

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* See Campbell, Mosses and Ferns, 300. 1895.

Having thus defined our field, we should have, for the consideration of the problem before us, some conception of what sort of plant the earliest Angiosperm was. In the absence of geological evidence this conception must be purely hypothetical and, basing it on a generalization which would admit of the differentiation from it of all the varied forms of the modern group of Angiosperms, we can see that it must have been a plant of very simple organization indeed. For our present purpose we need not concern ourselves with any other organs of this primitive Angiosperm than the leaves which, from the point of view of the proposed generalization, must be conceived of as hardly more than the bare rudiments of leaves, mere sheathing scales at the nodes of the plant, serving slightly, if at all, the function of assimilation which was still subserved, as in its ancestors, by the general surface of the plant, but confined chiefly to that of protection. The primitive leaf was probably parallel-veined or approximately so, giving rise in its earlier differentiation to the parallel-veined leaves of the Monocotyledones. The geological evidence indicates that these appeared before the Dicotyledones* which must have sprung from them later at one or more unknown points, and netted-veined leaves are of a more recent evolution. Consequently the tendency of aquatic Dicotyledones to revert toward monocotyledonous structure is rather a case of atavistic degeneration than an indication of the origin of Monocotyledones from Dicotyledones in ancient times through the effects of aquatic habit.†

Now, as advance in evolution proceeded, the need of greater assimilative capacity arose and, as the foliar organ was the one best adapted for specialization in this direction, it was the one upon which the office devolved. Every botanist knows what an endless variety of forms and special adaptations of particular foliar parts have arisen in the course of evolution which was inaugurated when this setting aside of the leaf to bear in future the weight of the assimilative function took place, or rather when this additional function was placed upon it, for the old protective function has always been retained, though it has become less noticeable as the new function has overshadowed the old.

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*Professor L. F. Ward. Sketch of Paleobotany. Fifth Ann. Rep. U. S. Geol. Surv. 448, 1885. Professor A. C. Seward, on the contrary, does not believe that we have satisfactory evidence of pre-Cretaceous Monocotyledones. Notes on the Geologic History of Monocotyledones. Annals of Botany, 10: 220. 1896.

†See Rev. George Henslow. Jour. Linn. Soc. Lond. 29: 485-528. 1893.

There has been in the line of vegetable descent a progressive development of the foliar organ, and a history of this development, together with that of other organs, if it were obtainable, would give us a complete phylogeny of the flowering plants, and leave no morphological problem unsolved,* but as the geological record is very incomplete, and we have in the lower Cretaceous an already well developed and much differentiated angiospermous flora of the earlier history of which almost nothing is known, we must seek other sources of information in determining the homologies of parts. At this juncture we may safely follow the example of the zoölogists and turn to embryology for the evidence which geology, as yet, refuses to give except in fragments Among animals, as the phylogeny and ontogeny are found to parallel one another, so we may feel confident they will be found to do among plants when the geological record shall be more completely unearthed.

It has become a well established part of the theory of evolution that each individual organism epitomizes more or less fully in its development the historical steps in the evolution of the type to which it belongs.† By the application of this law of recapitulation to the development of plants we may arrive at valuable and trustworthy conclusions. The question would at once be asked, where shall the embryology of the flowering plants be studied, and the answer would naturally be, in the development of the seed in the ovary. And here indeed, we trace in outline an epitome of the course of development from the simple unicellular organism, represented by the fertilized egg-cell of the ovule to the highest thalloid form, the "embryo," with its bud (plumule) which is to develop into the full-formed plant perfect in all its parts. For a summary of the further development of the Angiosperms we must look to the growing bud which is the essential reproductive organ of the sporophyte stage and, doubtless, a more primitive one than the seed, for it is common among the more ancient Pteridophytes and these have no seed. The embryo of flowering plants does, however, correspond pretty closely to that advanced stage of development of the egg-cell of some of the higher Pteridophyta now generally spoken of as the embryo and should be regarded as a young plant in a state of arrested development. In this state it remains during a period of rest, in a highly specialized envirońment in the seed, awaiting favorable conditions for farther growth. Because of the highly specialized environment of the embryo, it has itself become correspondingly specialized and has been variously modified to suit the special conditions of its surroundings. The plumule cannot then be regarded as any longer representing a primitive form of bud and its development is so altered by secondary modifications that the series of phylogenetic changes is disguised and imperfectly represented. A parallel case is found among animals in the development of Echinoderms, in which the changes that have taken place through secondary modification are so great that the relationship of the group cannot be satisfactorily determined by developmental evidence.

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* "On this same view of descent with modification most of the facts in morphology become intelligible, whether we look to the same pattern displayed by the different species of the same class in their homologous organs, to whatever purpose applied, or to the serial and lateral homologies in each individual animal and plant." *Charles Darwin,* Origin of Species, 1859. Am. Ed. 6, 2. 264. 1889. See also p. 239, *et seq.*

† This theory, known as Von Baer's law, was promulgated by that scientist in his Ueber Entwicklungsgeschichte der Thiere, 224. 1828-37.

See also F. M. Balfour. Comparative Embryology. Ed. 2, 1: 2. 1885.

Opposed to this law is Adam Sedgewick. On the Law of Development commonly known as Von Baer's Law. Quar. Jour. Mic. Soc. (II), 36: 35. 1894.

It is not then in the seedling that we should expect to find representations of primitive leaf-forms, though later ancestral forms paralleling those of fossil leaves, of which we shall speak, are found in some seedlings, as for example in *Liriodendron.* But it is in the growth of the less specialized buds developing under more primitive conditions that we should expect to find them. Such buds are the ordinary leaf-buds of perennial plants, and especially those occurring on basal and subterranean portions which I conceive to develop under conditions somewhat more primitive than is the case with aërial buds. But in both these the recapitulation of the development of leaf-forms may be traced with a considerable degree of confidence, from the primitive sheathing protective scale to the most highly differentiated and complex of modern leaf-forms.

It is at this point that the fragmentary geological evidence sheds its strongest light on the problem under consideration. In the Cretaceous and Tertiary floras which preceded the modern, the present degree of differentiation had not as yet been attained and but few modern species made their appearance before the close of the Tertiary.* The species, however, which immediately preceded those which now exist were very closely related to them, being their immediate ancestors, and differed from them only in showing a somewhat lower degree of differentiation, and their leaf-forms are accordingly more primitive than those of the existing species which have descended from them.

Now it is a well-established fact that the lower leaves of young branches and shoots, and especially of those which spring from the stumps of felled trees, are frequently unlike the adult forms which occur higher up and bear a close resemblance to the fossil leaves of extinct species, so close indeed, as oftentimes to be indistinguishable from them. This is strong evidence in favor of the doctrine that the lower foliar organs represent not reduced leaves, as botanists have commonly supposed,† but the primitive foliar organs, and that in an ascending series from the lowest scale to the mature adult leaves of the upper part of the stem, giving a more or less perfect summary of the phylogenetic development of the foliar organ from the most primitive type upward to the most highly differentiated.‡ In other words, a single stem may represent the whole phylogeny of the foliar organs of its type. It is true that there are simple leaf-forms which have become so by reduction but, as an organ cannot be reduced until it has been developed, these are to be looked for above and not below the perfect leaves, and are found in bracts, involucral scales and the parts of floral envelopes, reduction taking place in inverse order to the course of development, and only the most primitive structure, the simple sheath, persists in the petals of most flowers. Reduced leaves are also common in parasites, and in the flora of desert regions as is well illustrated in some of the Leguminosæ of Australia the leaves of which are little more than spines, or are developed into bladeless phyllodia, while in the seedlings the ancestral pinnate or bipinnate forms occur.*

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* Our modern species of *Corylus* are recorded from the Eocene by Professor J. S. Newbury. Later Extinct Floras of North America. Ann. N. Y. Lyc. Nat. Hist. 9 : 59–60. 1868.

† See DeCandolle. Org. Veg. 2 : 212 1827.

‡ "Most modern botanists now regard the varying forms of leaf seen on young shoots and near the base of trees as valuable hints at the probable stages through which the final forms have passed in the history of their development." Professor L. F. Ward. Proc. U. S. Nat. Mus. 11 : 41. 1888.

We thus have shown in each season's growth of a plant, though not clearly in annuals because disguised in the seedling, a more or less complete series of foliar organs which may for illustration be compared with the vertebrate series among animals, the lowest leaf-scales being comparable in degree of development to the simple structures of the fishes and the most highly developed leaves to the complicated ones of mammals. Each leaf in the series is equally perfect for the function it is intended to perform, but the lowest of a lower type of organization, as are the fishes, and representing an earlier stage in the phylogenetic series.

Now in animals we look to the developing egg of the more generalized fishes for the least abbreviated embryological recapitulation of the early development of the vertebrate branch, for in the mammals the early stages are passed through so rapidly and with so many disguises as to be of comparatively small importance in giving the history of the branch, unless viewed in the light of the embryological development of the lower types. So the lower foliar organs of a branch or shoot are embryologically of far greater importance than the upper, for in the beginning of the development of one of the upper leaves we have but the early stages of a highly organized appendage. These early stages are consequently abbreviated and more or less disguised. The formation of the stipules in the growth of the upper leaves is therefore not a salient point in the consideration of our problem though it has had much stress laid upon it, yet it is of interest to note that in general the stipules appear earlier than the leaf-blade, thus giving evidence that they are of more ancient origin. It may be added,

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*See Sir John Lubbock. On Seedlings. 1: 474. 1892. See also p. 440 as to the similar case of *Lathyrus Aphaca*.

and it is a matter of common observation, that the petiole is the last portion of the leaf to develop ontogenetically and is therefore to be regarded as the most recent part to be added phylogenetically. This helps to explain the common occurrence of sessile and petiolate leaves even in different species of the same genus, as variation more readily occurs in recent than in ancient structures, while on the contrary it has been a matter of remark among even the earlier botanists that stipules when they occur usually characterize all the species of a family, an additional evidence of the antiquity of their origin.

Let us now take up, in the light of the foregoing conclusions the consideration of the destiny of the primitive foliar organ as it has been modified and developed in the course of evolution. For convenience in making our inquiry, I would divide the primitive leaf into the central-basal, axial, apical and lateral portions. Each of these figures prominently in the evolutionary history of foliar organs, for from the original condition there has been progressive development along several lines of varying degrees of relationship and the morphological result of the development of the several parts has been quite different in the divergent groups, so much so as to render the question of homology a doubtful one to many minds. We shall endeavor to establish its reality.

The lamina of the leaf, as we shall see, has been developed chiefly from the apical portion, usually from scarcely more than a mere point, though it may also include the axial and lateral portions. The true petiole, when present, is developed from the axial portion,* the sheathing petiole from the central basal together with the lateral portions, stipules and structures of the same signification from the lateral portions. It is with the lateral portions, therefore, that we are chiefly concerned.

With reference to the formation of stipules there are three principle types of leaf-development: that in which the several portions of the primitive leaf have developed together into a simple unappendaged blade, that in which a sheathing petiole is formed with or without a ligule or ochrea, and that in which stipules properly so-called are present.

In the first and simplest case the development of all the parts together gives rise to such leaf-forms as are found in *Vaccinium* and *Sassafras*, the principal portion of the lamina being formed by the development of the apical portion, but including at the base the lateral, central-basal and axial portions which are contracted below into a short petiole.

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*See S. H. Vines. Text-book of Botany, 1: 49. 1894.

If we observe the development of the leaf in *Sassafras* the relative growth of the several parts can be readily traced. The first four leaves (fig. 1) are very simple. In the fifth (fig. 2) considerable development has taken place. The apical portion, now forming about half of the organ, is provided with the three typical veins as they appear in the adult leaf, but starting out separately from the very base. The lateral portions have reached their highest development and each is furnished with a pair of veins. In the sixth leaf (fig. 3) there is a very close approach to the adult form. The upper part has expanded and the lower parts have elongated, removing the point of separation of the three principal veins of the leaf to a considerable distance from the stem. At the same time there has been a basal contraction looking toward the formation of the petiole with a considerable degeneration of the lateral portions, one of the veins having disappeared from each of them, while the other has become associated with the midvein. The seventh leaf (fig. 4) represents the unlobed adult form and differs but little from the sixth.

A similar condition is observable in *Ailanthus glandulosa* Desf. (figs. 5–10), but resulting in this case in the final separation of the lateral portions as small gland-bearing fugacious stipules, comparable to those at the base of the leaves of many of the Ranunculaceæ. The comparison of *Sassafras* and *Ailanthus* shows how small a difference in development may determine a leaf as stipulate or exstipulate.

The case of *Syringa vulgaris* L. is like that of *Sassafras*, though more difficult to trace, owing to the larger number of veins in the leaf, but the homologies of parts may be followed more or less distinctly from the second leaf up to the sixth, the first adult leaf (figs. 11–14). The lateral portions are seen to have degenerated almost entirely and, their bundles having disappeared, they remain only in the margin of the petiole.

The Compositæ furnish examples of a similar course of development but often with a closer approach to the true stipular condition, as the lateral portions are supplied with vascular tissue by small branches coming off at the base of the leaf from the main lateral bundles.

In *Erigeron annuum* (L.) Pers., for example, there are three fibro-vascular bundles in the leaf-trace which pass up through the central portion of the petiole, converging as it narrows. But almost immediately on their departure from the stem each of the lateral bundles gives off a branch in the same manner as when true stipules are present. This branch forks at once and supplies the wings of the petiole. In the cauline leaves (fig. 15) its branches can be distinctly traced into the lower lobes of the leaf. The basal leaves of *Aster undulatus* L. show a condition very closely similar to that found in *Erigeron annuum* (L.) Pers., but in the cauline leaves there is a considerable modification by which the large lobes of the base of the petiole (fig. 16) are formed. The stipular bundle curves outward through the lobe giving off branches which form a net-work supporting its parenchyma. It then passes up through the wing of the petiole and into the basal part of the leaf. In *Solidago juncea* Ait., there are eleven bundles in the leaf-trace and a stipular bundle is given off on each side, supplying the margins of the petiole. *Artemisia vulgaris* L. affords a very interesting variation. The lateral portions of the primitive leaf have branched in a very curious manner (fig. 17), forming several small leaflet-like appendages to the base of the petiole. That they belong to the lateral portions and are stipular in their character is shown by the fact that they are supported by branches of the stipular bundle which is given off a little higher up than in *Erigeron*, passes on through the wings of the petiole after giving off the branches and enters the base of the blade as in other cases. This is the nearest approach to the true stipular condition that I have observed among the Compositæ.

The embryonic development of the foliar organ among the Compositæ is in general too much abbreviated to give much evidence in the consideration of the present question, and it should be so expected from the position which the family holds at the head of the vegetable kingdom.

Petioles of the kind seen in this type of leaf-development are very often short and usually more or less margined or winged by the contracted basal parts of the lateral portions of the primitive leaf. They are evidently genetically different from the petioles of stipulate leaves which are developed by the elongation of the axial portion alone. Sessile leaves also are of this type, hence the absence of stipules, the stipular tissue being incorporated into the basal part of the blade. But even where stipules are present, the lateral basal portions of the leaves are often in the closest anatomical relation with the stipules. This may be seen in *Viola obliqua* Hill (fig. 18) in which, near the bundle which passes into the stipule, a similar one arises, takes its course up the petiole supporting its narrow wing and is distributed to a small part of the basal portion of the lamina. We shall find several cases similar to this when we come to the consideration of the Rosaceæ. There is in this a suggestion of the occasional separation of only a part of the lateral portions to form the stipules and the incorporation of the remainder into the petiole and blade.

The second case is that of the sheathing petiole as it occurs in the Graminæ, Araceæ and Umbelliferæ. In this case the central-basal portion of the primitive leaf is very largely developed and with it the lateral portions which form the margins of the sheathing petiole. The lamina and true petiole are later developments of the apical and axial tissues. We are strongly supported in this view by the fact that the sheathing petiole is interchangeable with petioles of the ordinary type accompanied by stipules. This occurs in the Umbelliferæ. In *Hydrocotyle* and a few other genera the sheathing petiole is wanting and stipules are present. The closely related *Aralia racemosa* L. also has stipules. Still more striking is the case of *Comarum palustre* L. in which the basal leaves have the sheathing petiole remarkably developed with no indication of stipules (fig. 19), while the upper leaves possess well developed stipules adnate for not more than half their length (fig. 20).

But the identity of the marginal tissue of sheathing petioles is perhaps best shown in the Ranunculaceæ. In the upper basal leaves of *Ranunculus bulbosus* L., the separation of the lateral portions is seen actually to have begun, presenting exactly the appearance of adnate stipules. The development can be clearly traced from below upward. The first leaf has a short sheathing petiole of the ordinary type (fig. 21). This is slowly modified till in the fourteenth leaf (fig. 22) the vascular bundles have drawn closer together, the sheath has grown shorter and the broad lateral portions, hyaline in texture and requiring no special support other than that of the surrounding leaves, are rounded off distinctly at the top at the point of beginning of the true petiole. In the fifteenth leaf (fig. 23) there is a further reduction in size and the tips of the lateral portions are free. Another interesting case among the Ranunculaceæ is that of *Thalictrum polygamum* Muhl. in which the sheathing petiole is of a very generalized type (fig. 24). The lateral portions are chiefly hyaline, though sometimes faintly netted-veined and their margins turn in at the apex and meet in the central dorsal channel of the petiole at its base, forming a ridge between the sheathing and true petioles. This ridge supports a very narrow hyaline membrane which appears to me as the rudiment of a ligule. It would become typical by a little further development of marginal tissue. I believe this to be the origin of the ligule wherever it occurs, though it does not appear so clearly evident in highly specialized groups, nor should we expect such to be the case. There is also present at the first and second forkings of the petiole a transverse hyaline scale very much like a ligule.

It is noteworthy that the ligule always occurs in connection with the sheathing petiole, as in the Gramineæ and Cyperaceæ, or where there is evidence that there has been a sheathing petiole which has disappeared by degeneration, leaving the ligule axillary as in some of the Naiadaceæ which we shall presently consider.

When the ligule has developed sufficiently to require special support, it is supplied by the introduction of vascular bundles. These bundles have their origin most frequently as tangential branches of the main leaf-bundles at their point of passage from the sheathing petiole into the true petiole, or, where the latter is undeveloped as in the grasses, into the blade. This mode of origin of the ligular bundles is seen in some of the tropical grasses and in the ligular portion of the stipule of the Naiadaceæ and the ochrea of the Polygonaceæ. *Richardia* shows an exceptional venation of the ligule.

The best marked examples of the sheathing petiole among the Monocotyledones are found in the Araceæ, the Cyperaceæ and the Gramineæ. If we examine a developing plant of the common hot-house calla (*Richardia Africana* Kunth.), the first leaf (fig. 25) is seen to be a short, broad sheath, the second (fig. 26) has increased to a considerable length and the apical and axial tissues have developed into a minute blade and petiole. The third leaf is of the adult form, but smaller, though all the parts have increased very much in size. This is contrary to what is observed in *Ranunculus* where the sheathing petiole degenerates while the other parts advance. The margins of the sheathing petiole of *Richardia* curve inward at their apices and meet in the middle line of the leaf as in the case of *Thalictrum polygamum* L., but they are much broader and form a distinct ligule which is supported by the incurving and union of the marginal veins of the sheath instead of by tangential branches. In *Arisæma triphyllum* (L.) Torr., the transition is not so well marked, owing to the small number of leaves the first of which is but a sheath as in *Richardia*, while the second bears a mature lamina.

Scirpus polyphyllus Vahl. (fig. 27) will serve well to illustrate the ligule in the Cyperaceæ. It is but little developed as a slight hyaline outgrowth upon the ridge at the union of the sheath and lamina, but the sheath is closed, as is typical in the family. and a little farther development of marginal tissue would produce an ochrea. Typical of the ligule in our common grasses is that of *Phalaris arundinacea* L. (fig. 28). It consists of a considerable outgrowth of hyaline tissue which is continuous laterally with the marginal hyaline tissue of the sheath. This continuity strongly supports the position taken as to the origin of the ligule. The purpose of the ligule is evidently to prevent the flow of water from the upper parts of the leaf down between the sheathing petiole and the stem which together with the axillary bud it invests and protects, and neither the ligule nor the primitive ridge which bears it are found in those cases where the sheathing petiole does not closely invest the stem, at least in the early stages of growth, and its purpose could not be in any considerable measure fulfilled.

The usually axillary position of the "stipule" in the Naiadaceæ has occasioned considerable discussion as to its real relation to the ligule of grasses and to stipules proper. That it is in reality a development of the lateral portions of the primitive leaf, and that it corresponds to the ligule together with the margins of the sheathing petiole of grasses and is rendered more or less nearly axillary by the degeneration of the central-basal portion, becomes clear from the fact that in some species of Naiadaceæ the sheathing petiole retains a considerable degree of what should be regarded as its ancestral development, and a condition approaching that which occurs in grasses is found. *Potamogeton crispus* L. is one of our species which will serve well for an illustration. The first leaves do not develop a blade, but the lateral and central-basal portions are well developed. In the adult leaves there is present a true sheathing petiole (fig. 29). The fibro-vascular bundles of the central-basal portion pass into the blade, giving off tangentially, at the point of transition from sheath to blade, the bundles of the ligular part of the stipule. The bundles of the lateral portions do not in this case curve about to join those entering the blade but are prolonged upward, remaining parallel and supplying the lateral portions of the stipule with supporting tissue directly. In *Althenia filiformis* Petit. (fig. 30), the conditions are more primitive in the larger relative development of the lateral and central-basal portions. In *Ruppia* the ligule is not developed, and the tips of the lateral portions are free as in ordinary adnate stipules.

The condition found in *Potamogeton* is almost exactly repeated in *Polygonella articulata* (L.) Meisn. (fig. 31). The ochrea is cylindrical, surrounding the stem. The central-basal portion is long and narrow, bearing at its apex the terete lamina which is deciduous before flowering. The lateral portions form the principal part of the sheath, are parallel veined with a few anastomosing bundles and are prolonged above the central-basal portion, growing in along the ridge between it and the lamina. This middle portion shows its origin by a deep median sinus and receives its bundles typically as tangential branches from those entering the lamina. We do not have then in *Polygonella* a typical ochrea as it occurs in *Rumex* and *Polygonum*, where, because of the small development of the central-basal portion, the sheathing petiole is very short or almost wholly wanting. The lamina, being of much greater importance than in *Polygonella*, receives all the bundles of the leaf-trace. They are more or less abruptly deflected into the true petiole, generally developed in these genera, according to the degree of degeneration of the central-basal portion. The lateral portions receive their supporting bundles as branches of the lateral ones of the leaf-trace. In *Polygonum sagittatum* L. (fig. 32), the marginal tissues do not extend across the petiole and we have a stipule opposite the leaf. In *Rumex crispus* L. (fig. 33) and *Polygonum Virginianum* L. (fig. 34), the ochrea is complete and the axillary parts receive the typical tangential bundles.

The ochrea of palms is doubtless of the same character, though I have not had opportunity to examine its anatomical structure. In those species which I have examined morphologically, the case is that of the ochrea associated with a remarkable development of the sheathing petiole. There is no true petiole and the ligule may be seen even a little above the base of the blade on the upper surface of the midrib. From this point the lateral portions may be traced down the margins of the sheath, though dried up and very much torn and broken by the more rapid development of the central tissues, till they unite with those parts which in their development have formed the "ochrea." The degeneration of the sheathing petiole with the probable concomitant formation of a true petiole would give the same conditions as in *Polygonum* with its typical ochrea.

The ochreate stipule of *Platanus* differs little morphologically from the typical ochrea, except in the absence of development of the central-basal portion and the possession of a horizontal limb, but there is no fibro-vascular support for the ligular part and this usually splits, leaving apparently a single stipule opposite the leaf.

The case of the tendrils of *Smilax* is one which has occasioned much discussion, but the embryological together with the anatomical characters make it sufficiently clear that in *Smilax* the tendrils are true stipules found in connection with the sheathing petiole. If a young shoot of *Smilax rotundifolia* L. be examined, the first leaf (fig. 35) is seen to be of the typical primitive form. In the second (fig. 36), the apical portion has developed into a blade of considerable size and there is a well-marked sheathing petiole. In the third (fig. 37), the true petiole has begun to develop, the central-basal portion is degenerating and at the same time the lateral portions have begun to separate, forming rudimentary tendrils which in the adult leaves come to considerable length by secondary development in adaptation to their new and unusual function of support. In cross section the bundles of the tendrils are seen to arise as branches of those of the petiole, so that anatomically, as well as embryologically, they answer to true stipules.

Pastinaca sativa L. (fig. 38) furnishes a good example of the sheathing petiole among the Umbelliferæ. The lateral portions are broad and furnished with several vascular bundles parallel with those of the central basal portion. The lateral portions remain of considerable breadth to the top where they are distinctly rounded off, and their bundles, with the exception of two or three of the exterior ones, curve around and unite with those entering the petiole. This free condition of the exterior lateral bundles with the anastomosing network between them shows a considerable degree of approach to the true stipular condition.

In the third case true stipules are developed. They are formed by a very early separation of the lateral portions from the main body of the primitive leaf, a separation which can be very clearly traced progressively in the embryological history of leaf development. The function of the lateral portions in their primitive connection with the main body of the foliar organ is, in common with the other portions, protective, and while the apical portion, having had placed upon it the special function of assimilation, goes on in its development together with the accessory axial portion in adaptation to this purpose, the lateral portions usually serve their ancient function only, sharing it with the central-basal portion when this has not disappeared by degeneration. The central-basal portion also supports the main body of the leaf, a function from which the lateral portions have been freed by separation.

It is in consequence of this separation that all the main vascular bundles of the leaf-trace in the third type of leaf-development are deflected toward the central one that they may pass up through the petiole into the lamina and give the required support to these important parts. The support of the lateral portions is left to comparatively small lateral branches from the two exterior bundles of the trace, evidently developed expressly for the purpose. This we may conclude, since vascular tissue is the most modern of plant tissues and introduced because of the necessity of support in the evolutionary development of the primitive ground tissues. It would, therefore, follow and not precede the evolution of leaf-forms, being introduced where needed and disappearing again when degeneration or other support of particular parts renders its presence unnecessary. This will appear in some of our examples. In the first and second types of leaf-development the lateral portions may retain in greater or less degree their independent venation.

As the other portions of the primitive leaf have been so wonderfully modified in the course of their development and altered from their original condition, so the freed lateral portions to which we may now apply the term *stipules* have not retained their primitive proportions in adult leaves nor the identity of all their parts. But as the central basal portion has often almost wholly degenerated, the same thing has happened to the basal parts of the lateral portions. The parallel degeneration of the two portions has brought the stipules into closer and closer apparent relation to the stem, so much so as to lead to the enquiry whether they are not accessory leaves and to suggest their origin from the reduction or lack of development of a portion of the leaves as in *Selaginella* and their subsequent association in close relation to the larger ones, but in all my investigation I have not found the slightest evidence in support of this theory. The degeneration of the stipules may continue until they become vestigial or finally disappear altogether. This is evidently the case in those families of plants a few species only of which still possess stipules, as for example the Caprifoliaceæ.

But opposed to the basal degeneration of stipules, there has very commonly been a longitudinal development corresponding to that by which the lamina has been evolved. This has resulted in the adaptation of the stipules to the peculiar requirements of each genus and species. Often in this secondary development they remain membranous, serving the protective function only, and when free are early deciduous. But in numerous cases they have acquired the assimilative function also, developing abundant chlorophyll and sometimes, as in the pea (*Pisum sativium* L.), becoming of equal assimilative importance with the lamina. In *Lathyrus Aphaca* L., they even replace it almost entirely.

Among all these varying forms we should expect to find closer similarities in those plant groups of nearer relationship as we do in floral structures, and conversely these similarities of foliar development should also point to relationship, due allowance being made for parallel development in adaptation to similar environment and for secondary functional modifications which find morphological expression. Also in types more recently evolved and more highly differentiated wide divergence from the typical mode of development may be looked for. The Caprifoliaceæ, before mentioned, are of such a type, with stipules usually wholly aborted;

another is the family of the Rubiaceæ with anomalous stipular development in the group of the Stellatæ. The oaks also, though of lower organization, are an advancing type and still actively undergoing differentiation as evinced by the close relationship and difficulty of determination of the species of any given group. In this genus all but the upper part of the primitive leaf has disappeared by degeneration even in the earliest stages represented in embryonic leaf-development, and the well developed stipules are distinct and separate from the very base of a developing shoot. Not until the fifteenth node, in *Quercus rubra* L. (fig. 39), is there any appearance of lamina. The apical portion of the protophyll must however be regarded as potentially present between the stipules at their base. It begins its development unusually late in the series and exhibits several stages, of which the twentieth leaf (fig. 40) is illustrative, before reaching adult size. The axial portion of the protophyll being aborted, the petiole, here again a short one, is formed by the contraction of the basal part of the lamina itself. The case of *Fagus* is very similar, but the lamina appears as early as the eighth node (fig. 41), indicating a less degree of specialization. In related genera a different course has been followed. The lamina develops still earlier and the stipules of the lowest nodes are united, separating only on the appearance of the first accompanying lamina.

In the family of the Juglandaceæ the genus *Hicoria* furnishes a very interesting example. The lower foliar organs are of the primitive type with an unusual development in size in some species. The transition to the adult leaf-form is commonly rather abrupt, but I have observed, in both *Hicoria alba* (L.) Britton and *H. microcarpa* (Nutt.) Britton, the frequent occurrence of intermediate forms, the lateral portions remaining as typical adnate stipules (fig. 42).

I have not seen the typical representation of embryonic leaf-development better exemplified than in the case of *Baptisia tinctoria* (L.) R. Br. where at a glance one is struck with its clearness. It is also especially full and accurate as occurring in the development of subterreanean buds. The first five leaves are extremely primitive, completely surrounding the node, though only slightly developed on one side. The fifth (fig. 43) shows at its apex a minute apical tooth, the beginning of the lamina which is farther developed in the sixth leaf. In the seventh (fig. 44) the three leaflets are plainly distinguishable, the petiole has begun its development and the separation of the stipules has made considerable advance. The ninth leaf (fig. 45) is well developed, with the large stipules still showing considerable adnation. But in the tenth (fig. 46) they are wholly free and much reduced, and higher up disappear altogether. We could hardly have a more complete series in illustration of the formation of stipules than this, giving as it does all the stages from an extremely primitive leaf-form to that very highly organized condition where the stipules have entirely disappeared. By a comparison of the venation in the seventh and ninth leaves, it will appear that the separate condition of the stipules has been attained in the manner already described, partly by the formation of an apical cleft, partly by the degeneration of the central-basal portion bringing the base of the cleft lower down. Meanwhile there has also been a considerable apical development of the stipule itself. But this increase in size is lost again in the tenth leaf and the reduction continues to final abortion. *Melilotus alba* Lam. presents very similar though somewhat less primitive conditions.

While considering leguminous plants, a few words concerning stipels, which are so characteristic of the family, would be in place. They have been denominated as "the stipules of leaflets," but I am convinced that they have no connection with stipules whatever, but that they represent rudimentary leaflets which have their origin in a tendency to increased compounding. The habit has become so fixed in the Leguminosæ that evidence of its origin is seldom met with. I have however seen, in *Lespedeza capitata* Michx., one of the earliest leaves with the terminal leaflet only developed and the two lateral ones represented by stipels.

I have found more light on the question in other families where the same tendency to increased compounding often occurs. In *Sanguisorba Canadensis* L. (fig. 47) for example, very vigorous plants sometimes show rudimentary leaflets, more developed indeed than typical stipels, but in the same position. Their character as leaflets of secondary rank is evinced by their occasional removal to a little distance from the primary petiole. A more striking case is that of *Sambucus Canadensis* L. In this species the leaves of young shoots springing up where the bushes have been cleared away are frequently partially bicompound and there are all gradations between the ordinary pinnate form and the bipinnate condition (figs. 48–50). In this case it is remarkable that the first appearance of the secondary leaflet is in the shape of a small body with both the form and position of a stipel, with the same small supporting vein and differing only in greater thickness. These facts seem to give evidence sufficiently conclusive that stipels are in reality rudimentary leaflets. That their development is not confined to the Leguminosæ is farther shown by their characteristic occurrence in *Staphylea trifolia* L.

Another frequent foliar variation among the Leguminosæ is the development of the phyllodium, which might be thought to have some connection with stipules, but the presence of both together in some genera disproves the idea.* The stipules in the Leguminosæ often take the form of spines which serve for the general protection of the plant. We have an example in the well known *Robinia Pseudacacia* L. (fig. 51). In some of the tropical Acacias, as for example *A. spadicigera* C. & S. (fig. 52), they take the form of enormous hollow horns which are appropriated as homes by some species of ants.†

Sambucus Canadensis L. presents another remarkable character. The leaves of the vernal shoots from subterranean buds are furnished with stipules of the same form and in the same position as those of *Sambucus Ebulus* L., but smaller. There are four of them at each node, they are ovate or nearly orbicular in form, small, rather fleshy and persist but a short time. Each is supplied with a small vascular bundle, originating as a branch of the nodal girdle which connects the leaf-traces. These facts give evidence of the close relationship of these two species of *Sambucus*, and of the characteristic presence of stipules in the ancestral form. In *Sambucus Ebulus* L., they are still typically developed, but in our species have become so far vestigial as to appear only in connection with the early leaves of shoots from subterranean buds, an additional evidence of the importance of the leaf-forms successively developed from such buds, in their bearing on the evolutionary development of modern adult forms.

If now we turn to the family of the Rosaceæ we shall find many illustrative examples of the same facts as those born out in the case of *Baptisia tinctoria* (L.) R. Br. But it frequently happens that basal degeneration does not take place or is only partial, resulting in the adnate stipules characteristic of so many genera and species of the family. *Agrimonia striata* Michx., in the development of its subterranean buds in the spring, presents an excellent series of embryonic leaf-forms. The lower ones are all simple sheathing scales completely surrounding the stem at their insertion. Not until the eleventh leaf (fig. 53), which is three-toothed at the apex, does the differentiation of parts begin. The central tooth is the beginning of the blade with its petiole; the lateral portions with their tips now free are the stipules. To say that they are "adnate" indicates only that they retain their primitive connection with the central-basal portion. In the twelfth leaf (fig. 54), there has been some basal degeneration, as shown by the lower point at which the three main bundles of the leaf converge and the lower position of the zigzag plexus of the stipular veins. The free tips, on the other hand, have increased in size and a small blade supported by a petiole is present in consequence of the development of the central tooth. The fifteenth leaf (fig. 55) shows a stronger development of all the parts, and a branch of the main stipular bundle is seen to pass up the petiole. The adult form is attained in the seventeenth leaf (fig. 56). In it some further basal degeneration has taken place, but the adnation of the stipules is still very prominent.

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* Bentham and Mueller. Flora of Australia, 2: 304. 1864.

† Belt. Naturalist in Nicaraugua, 218. 1874.

Prunus Cerasus L. gives a very good morphological series, but the venation is obscure. A view of the several forms can be had by an examination of the tenth, thirteenth, fifteenth, sixteenth and seventeenth leaves (figs. 57–61). They show the transition from the simple primitive scale to the mature condition in which the stipules are rendered entirely free. The series is similar in *Rubus occidentalis* L., *Pyrus Malus* L. and *Pyrus communis* L. In *Rubus villosus* Ait. (figs. 62–66), the basal degeneration is not carried quite so far and the stipules in the adult leaf-forms remain adnate for some distance from the base of the leaf. The tips of the stipules have taken a larger comparative development than in *Agrimonia*. Anatomically, however, *Rubus villosus* Ait. resembles the latter in having a vein which enters the petiole, neighboring to the main stipular bundle much as in *Viola obliqua* Hill (fig. 18). The venation in *Pyrus Malus* L. (fig. 67) is still more like that in *Agrimonia*.

The stipules of *Fragaria* and *Rosa* show the highest degree of adnation and little, if any, basal degeneration seems to have taken place, though the lateral leaf bundles curve in toward the median one at but a short distance from the stem. This arrangement of the bundles is probably secondary in these forms for the purpose of giving a firmer support to the leaf by an axial concentration of the vascular tissue in the sheath and a corresponding thickening of the surrounding tissues, a firmer support than could be given by only three bundles if they did not converge till they approached the point of their entering the petiole. The venation of the stipules is also peculiar. In *Fragaria Virginiana* Duchesne (fig. 68), there is a single strong bundle running out into the free tip of the stipule. From this are sent out one or two weak veins above, and below there is a faint vascular network confined mostly to the region of the tip and extending in a long curve toward the outer portion of the base, where it gradually fades out without forming any connection with other vascular tissue below. This condition seems to indicate a former basal connection of these stipular bundles, either with the lateral bundle of the leaf or possibly with those of the stem, forming an additional leaf-trace bundle distributed to the stipules only. The former case is far more likely. A probable explanation of this degeneration of the basal stipular bundles can be found by a consideration of the conditions of the environment. All the leaves being basal, the stipules are clustered together and are supported by one another and by the surrounding soil. They are more or less fleshy, destitute of chlorophyll, and in their moist surroundings loss of water by evaporation is comparatively slight. All these circumstances lessen the necessity of the supply of fresh sap. The rapidly conducting vascular tissue has come into disuse, and its degeneration and disappearance is the natural consequence. The same arrangement in forms with leafy stems is not so readily explainable except by the supposition that the arrangement is ancestral. This seems rather evident in the case of *Agrimonia striata* Michx. (figs. 53–56), where the same condition of the bundles occurs, for the earliest leaves representing the ancestral forms develop under the same conditions as the adult leaves of *Fragaria*. But in *Rosa* it would be by no means clear did we not have such intermediate types as *Agrimonia*. *Rosa humilis* Marsh. (fig. 69) may be taken as typical of the genus. The venation of the tip of the stipules is nearly like that in *Fragaria*, but with a little larger development above the main bundle. The vascular network below is much more extensive and is reënforced by several small branches from the lateral bundle which enters the petiole, below the main stipular branch. This additional supply of vascular tissue is evidently rendered necessary by the exposure of the stipules to the light and air and the development of chlorophyll. It seems to be of secondary introduction.

The nearest approach to the stipular conditions occurring in *Fragaria* and *Rosa* which I have observed among the Leguminosæ is found in the adnate stipules of *Trifolium pratense* L. (fig. 70). There are two sets of stipular bundles. One of these supplies the tip of the stipule and consists of three veins of which the lowest corresponds to the single large bundle of the tip of the stipules of *Fragaria* and *Rosa.* The other has its origin as branches from the lateral bundle of the leaf-trace at the base of the leaf, the usual point of origin of the veins of free stipules. This set of veins is distributed to the lateral and basal parts of the stipules and apparently corresponds to the lower network of the stipules in *Fragaria.* These stipules are mainly protective in function. Their meshes are filled with hyaline tissue, but there is some green parenchyma along the veins.

Two very interesting cases in the family of the Rosaceæ are those of *Cliffortia graminea* L. f. of South Africa (fig. 71) and *Potentilla fruticosa* L. (fig. 72). In the former the leaves very closely simulate those of grasses with the linear lamina sessile upon a sheathing petiole. They differ in having the tips of the lateral portions (stipules) free instead of turning in across the insertion of the lamina to form a ligule. In the latter the conditions are very closely similar to those of the ochrea of *Polygonum.* There is a short sheathing petiole, above the apex of which the tips of the stipules rise. Each of them is supported by a strong vein which has its origin at the base of the true petiole. But instead of being free from one another as in *Rosa*, the stipules are connected back of the petiole by a hyaline ligular tissue. The lateral portions of the sheathing petiole are also united to one another on the opposite side of the stem, at least in young leaves, to a considerable degree. Thus an ochrea is formed, not quite a typical one it is true, yet more nearly so than that of *Polygonum sagittatum* L. (fig. 32).

The fact that such forms as these can occur in the same family of plants along with typical stipules, both adnate and free, goes to show how small is the real difference between the various stipular forms. Not all stipules possess supporting tissues but, just as is the case in the ligule of most grasses, may be without any fibro-vascular bundles whatever. This is the case in *Vitis*, in *Parthenocissus* and *Hydrocotyle*. *Vitis Labrusca* L. (fig. 73) shows a somewhat thickened central streak at the base of the membranous stipule, but in *Hydrocotyle Americana* L. (fig. 74), the thickness is uniform and the stipule very thin. These facts give some authority to the supposition that the pectinate interpetiolar appendages which occur in the Composite *Willoughbya scandens* (L.) Kuntze (fig. 75) are true stipules. They are hyaline in texture, without supporting tissue, and may possibly be merely of epidermal origin. To determine this point requires opportunity to examine their development.

It is of importance to state that the tendril of the Cucurbitaceæ, regarded by many as a stipule, has been determined by anatomical examination to represent the first leaf of the axillary bud.* The spines of *Xanthium spinosum* L., simulating stipules in position, are degenerate pistillate flowers. As proof of this, they often bear a greater or less number of hooked prickles like those of the flowers, and there may be a spine on one side and a flower on the other, showing them to be of the same significance.†

The stipules of *Comptonia peregrina* (L.) Coulter (fig. 76) denied by some to be properly so-called, do not differ anatomically from other stipules notwithstanding their peculiar morphology, and are to be included under the term. One of the chief reasons for their exclusion seems to have been the absence of stipules in *Myrica*. This is doubtless a case parallel with that of *Viburnum*, of which most of the species have lost their stipules by degeneration.

While it is not a generally accepted view, there is no good reason why stipules should not sometimes be distinguishable in floral parts. They are clearly present in the sepals of *Rosa* and *Rhodotypus*, and the smaller intermediate lobes of the calyx of *Potentilla* probably represent pairs of united stipules, one from each neighboring calyx-lobe in the manner of interpetiolar stipules.‡ The teeth of the filament in *Deutzia* are very suggestive of stipules in stamens, and the corona of *Silene* may very probably represent a ligule. The glands of the leaves of Ranunculaceæ which have been homologized with stipules, as already stated, can often be traced up into the flowers and are familiar in connection with the petals of *Ranunculus.*

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*See Lestiboudois, Bull. Soc. Bot. Fr. 4: 746–747. 1857. Cited on p. 6.

† See also Clos. Mem. Acad. Sci. Toulouse, (IV), 6: 66–75. 1875.

‡ See Engler and Prantl. Pflanzen Familien. 3· Abt. 3, 6. 1894.

One of the most interesting families of plants in the development of its stipules is that of the Rubiaceæ, the development being very unusual in the group of the Stellatæ. Though the foliar anomaly in this group was early remarked upon and was anatomically explained as early as 1840,* there are considerations which make its present discussion desirable.

In the greater part of the family the leaves are opposite, or occasionally in whorls of three as in *Cephalanthus occidentalis* L., and are usually stipulate. The stipules are of variable character and often interpetiolar, the adjoining stipules on each side of the stem being connate. In the group of the Stellatæ however, comprising ten or twelve genera, the stipules usually are apparently wanting and the leaves in whorls. There is a tendency toward a verticillate arrangement of the leaves in others of the Rubiaceæ, as shown by the frequent occurrence of whorls of three in usually opposite-leaved species. Now an anatomical examination of the whorled leaves of *Mollugo verticillata* L., *Silene stellata* (L.) Ait. f., *Leptandra Virginica* (L.) Nutt. and *Cephalanthus occidentalis* L. reveals the fact that in other families, as well as in the Rubiaceæ exclusive of the Stellatæ, each leaf of any whorl receives its fibro-vascular bundles directly from the cauline cylinder. But in *Galium* the case is different. Two leaves only of the whorl receive their bundles in the manner stated, and only these two produce buds in their axils. All the others receive their vascular supply from what may be termed a nodal girdle, each half of which is formed by the union of two bundles arising, one from each of the two leaf-traces in the same manner as those supplying stipules of the ordinary form. From this girdle arise the bundles which supply the additional leaves, whether there be only one on each side, as in *Galium circæzans* Michx. and *G. lanceolatum* Torr., two, as in *G. triflorum* Michx. and *G. tinctorium* L., or even three or four, as occurs in *G. Aparine* L. The distribution of the vascular bundles may be seen in a cross section of the node of *Galium tinctorium* L. (fig. 77).

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* See page 6.

This anatomical arrangement shows that the so-called additional leaves of the whorls in *Galium* are in reality stipules and that the Stellatæ agree with the rest of the Rubiaceæ in having opposite leaves. The tendency of the family however to produce verticillate leaves has been strongly felt in this group but has taken an unusual course, the increased assimilative area having been evolved through the stipules instead of by an increase in the number of true leaves. The explanation is thus made comparatively simple except in those cases where the number of stipules at a node is more than four.

As a general rule, in plants with stipulate leaves, each leaf is provided with two stipules. But when the leaves are opposite, the two on the same side of the node often coalesce, forming a single interpetiolar stipule, as in the case of *Cephalanthus* (fig. 78). That this coalescence is secondary is shown by the fact that the distal portions only of the veins of the two stipules have united. Now in the Stellatæ also, this must have been the original condition, but the interpetiolar stipules have been greatly developed to serve assimilative purposes, the veins having meanwhile united completely to form a midrib. The increase in size has advanced until in *Galium* the stipules are of the same size and form as the leaves and morphologically indistinguishable from them, except in *G. bifolium* where the stipules are smaller. In this condition they remain in the broader-leaved species, as *G. pilosum* Ait., *G. latifolium* Michx. and *G. lanceolatum* Torr. But in the narrower-leaved species, a still greater foliar expansion being desirable, separation has been re-accomplished, proceeding probably from the tip downward, as is illustrated in *Rubia peregrina* L. with whorls of four. In this species stipules are occasionally found with two midribs (fig. 79), most widely separated at the apex or even coalescing toward the base. In *Galium Aparine* L. and other species in which the number of stipules is abnormal, we may suppose this condition to have arisen from a repetition of the process of division which has produced the six-leaved whorls. This is not improbable, since even in the four-leaved forms the stipules have already entirely lost their original morphological character and have taken on a more generalized nature, making them fit material for development along new lines of evolution. Embryölogical evidence is not wholly wanting, although the family stands so near the head of the plant series. In

Galium Aparine L., in common with the six-leaved species, the earlier whorls are of four leaves only, representing the ancestral condition. In *Rubia tinctorium* L., the opposite leaves of the subterranean portion of the stem are exstipulate. At the first aërial node there is a whorl of four, interpetiolar stipules being present, and in the higher whorls there are six leaves.* This is a series of long range, though lacking in intermediate steps.

Another case in which there is present a nodal girdle from which the stipular bundles arise is that of *Humulus Lupulus* (fig. 80), but there are three bundles in each leaf-trace. They are placed at about equal distances around the circumference of the stem, and the girdle-bundles proper occupy only about one-third of the periphery on each side. From them a part of the stipular bundles arise, the remainder originating directly from the lateral bundles of the leaf-traces.

It would be to small purpose that examples should be further multiplied. From those already cited we may confidently deduce the following conclusions :

1. The sheathing petiole has its origin independently of the true petiole and is formed by a concomitant development of the lateral and central-basal portions of the primitive leaf.

2. The ligule is a special development of the apical parts of the lateral portions of the primitive leaf along the ridge between the sheathing petiole and the distal parts of the leaf. It may be supplied with veins either by the marginal bundles of the sheath or by tangential branches from those entering the blade. The sheathing petiole may disappear by degeneration, rendering the ligule axillary as in many species of *Potamogeton*.

3. The ochrea is related to the ligule and is generally associated with the sheathing petiole. It consists of the apical tissues developed in those cases where the sheathing petiole completely surrounds the stem or did so in the ancestral condition. The part of the ochrea posterior to the lamina or petiole may be called its ligular portion and is usually supplied by bundles arising tangentially from the main ones.

4. The lateral portions of the primitive leaf, when separated in greater or less degree, constitute stipules in the usual acceptation of the term. They are variously modified by subsequent evolu-

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*Sir John Lubbock. Jour. Lin. Soc. Lond. 30 : 504. 1894.

tionary changes, by increased development, by basal or total degeneration, by secondary adnations and various textural modifications. They receive their vascular bundles typically as branches of the lateral ones of the leaf-trace.

5. The lateral portions of the primitive leaf therefore represent in potential the ligule, the ochrea, the margins of sheathing petioles and stipules, but they are often incorporated with the other portions as the wings of petioles and as lateral basal portions of leaf-blades.

II.—*The Ascidian Half-Embryo.*

BY HENRY E. CRAMPTON, JR.

Read March 8, 1897

The development of isolated blastomeres of the ascidian egg has afforded a subject of considerable discussion on the part of many theoretical embryologists. Chabry* approached the subject from the experimental side, and, from the results of his many detailed observations and experiments, was led to the conclusion that one of the isolated blastomeres of the two-celled stage produced a strict half-embryo. As it was well known that the first cleavage-plane divided the egg into right and left halves, this conclusion seemed altogether probable and of considerable interest. A number of writers, however, among them Hertwig,† Driesch,‡ Weismann,§ Barfurth‖ and Roux,¶ were led, on the grounds of Chabry's results, to opinions more or less at variance with his. Barfurth considered Chabry to be in greater part correct. Roux and Weismann believed that during the later development the missing part was supplied by the other cells through "postgeneration." Hertwig states that, in his opinion, Chabry was in error; and Driesch also argued that a typical total development occurred. Finally, Driesch** in 1893 repeated Chabry's experiments, upon the eggs of *Phallusia mammillata*, and by the results wholly confirmed the theoretical conclusions of his previous paper.

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* Chabry L. Contribution à l'embryologie normale et tératologique des ascidies simples. Journ. de l'anat. et de la phys. XXIII. 1887.

† Hertwig, R. Urmund und Spina bifida. Arch. f. mikr. Anat. XXXIX. 1892.

‡ Driesch, H. Der Werth der beiden ersten Furchungszellen in der Echinodermentwickelung. Zeit. f. wiss. Zool. LIII.

§ Weismann, A. Das Keimplasma. 1882.

‖ Barfurth, D. Halbbildung oder Ganzbildung von halber Grösse. Anat. Anz. VIII. 1893.

¶ Roux, W. Über des entwickelungsmechanische Vermögen jeder der beiden ersten Furchungszellen des Eies. Verhandl. d. Anat. Ges. Wien. 1892.

** Driesch, H. Von der Entwickelung einzelner Ascidienblastomeren. Archiv für Entwick. der Organismen. I. 3. 1895.

Although at that time reluctant to admit anywhere the occurrence of "partial" development, Driesch has since proved, in connection with Morgan, the existence of a partial *early* development in the ctenophore egg.* And in a recent paper by the writer † it has been shown that the isolated blastomere of the snail possesses the power of forming only a corresponding portion of an embryo. In a later paper, Driesch,‡ developing an idea suggested by Prof. E. B. Wilson and myself (loc. cit.), recognized the existence of a series among animal eggs, from the nearly isotropic eggs of the medusa, Amphioxus, fish, sea-urchin, etc., at one extreme, to forms such as the frog and ctenophore, and finally to the snail, at the other extreme, where the blastomere possesses such an organization that but a part of an embryo can be formed and postgeneration cannot occur.

The ascidian egg, however, remained unexplained by the contradictory results of Chabry and Driesch. From this consideration the author was led to an examination of the facts in another ascidian. The results will, it is hoped, clear up the confusion to some extent, and will show how far the development is a "partial" one and in what respects it is "total."

The experiments were performed during the past summer at the Marine Biological Laboratory, Wood's Holl, upon the eggs of *Molgula manhattensis*, which grows very abundantly upon the piles and wharves at New Bedford, Mass. Artificial cross-fertilization was resorted to, and the eggs at the desired stage were spurted in a watch-glass by means of a fine spiral pipette.§ Those eggs presenting isolations were placed separately in watch-glasses, and camera drawings of successive stages were made at intervals, using a Zeiss oc. 4, and obj. C.

As to nomenclature, the system proposed by Kofoid || and ap-

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* Driesch, H., and Morgan T. H. Von der Entwickelung einzelner Ctenophorenblastomeren. Archiv für Entwick. der Organismen. II. 2. 1895.

† Crampton, H. E., Jr. Experimental Studies on Gasteropod Development, with an appendix on Cleavage and Mosaic Work, by E. B. Wilson. Archiv für Entwick. der Organismen. III. 1. 1896.

‡ Driesch, H. Betrachtung über die Organisation des Eies und ihre Genese. Archiv für Entwick. der Organismen. IV. 1. 1896.

§ As previously described in connection with the gasteropod experiments.

|| Kofoid, C. On some laws of Cleavage in Simax. Proc. Amer. Acad. Arts and Sciences. Vol. XXIX. 1894.

plied by Castle* to the *Ciona* egg has been used for obvious reasons. According to this system, now well known, each cell is designated by a letter referring to the particular quadrant of the four-cell stage from which it arose; in addition it receives an exponent denoting the generation to which it belongs, and a second exponent denoting its place in that generation, counting from below upward.

DETAILED DESCRIPTION OF CLEAVAGE.

A. *Normal Cleavage.*—The cleavage of the *Molgula* egg is precisely the same as that of *Ciona* and other ascidians, as far as it has been followed. Therefore, it is unnecessary to discuss the normal phenomena further than to emphasize a few of the facts which are important in connection with the cleavage of the fragments.

The first and second cleavage-planes are meridional, while the third is equatorial. An eight-cell stage results (fig. 1) which, seen from the side, consists of two tiers of four cells each. The upper tier is shifted anteriorly upon the lower, so that the *posterior upper* cells are in contact with the *anterior ventral* cells- This relation is constant, and characteristic of probably all ascidian eggs (Castle. loc. cit., p. 228). Passing to the 16-cell stage, all the eight blastomeres divide. The spindle axes are inclined in such a manner that the *anterior* products of the *anterior* cells (fig. 2: $B^{5\cdot 2}$, $b^{5\cdot 4}$) lie slightly *below* the median products; while the *posterior* products of the *posterior* cells lie slightly *above* the other cells (fig. 2: $C^{5\cdot 1}$, $c^{5\cdot 3}$). When activity is again resumed, the dorsal cells remain quiescent, while the ventral cells segment, and a 24-cell stage results (fig. 3). After a period of rest the dorsal cells pass into the same generation (sixth) with the ventral cells, and a morula of 32-cells results. Then the ventral cells divide at about the same time, while the dorsal cells remain quiescent, giving a 48-cell stage.

Further details are unnecessary for our purpose. We emphasize the fact that, beginning with the 16-cell stage, there is a well-marked alternation of activity between the cells of the upper and those of the lower hemisphere of the embryo.

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* Castle, W. E. The Early Embryology of Ciona intestinalis. Bulletin of Mus. of Comp. Zool. Harvard. Jan. 1896.

B. *Cleavage of the $\frac{1}{2}$ blastomere.*—As is well known, the isolation of an ascidian blastomere is effected by the death of its neighboring cell or cells, and not by an actual separation. The dead cell partially disintegrates and exerts upon the living cell no modifying influence, such as mechanical obstruction to rounding during division, etc.

$\frac{2}{4}$. At the normal time, viz: at the time of division of control eggs, the injured blastomere divides about equally (figs. 4 and 13). Often when the eggs are operated upon when passing into the 4-cell stage, evidence of division in the dead cell will remain. In such cases the division plane of the living cell is seen to be meridional and at right angles to the first. Therefore, it corresponds with the second cleavage-plane of the normal embryo. In all cases where it is possible to ascertain the facts this relation obtains. Driesch finds in *Phallusia* that no such constancy of relation exists.

$\frac{4}{8}$. After a normal period of rest the two cells divide at the same time. There are thus produced four cells which are arranged in a manner exactly similar to the half of a normal 8-celled embryo. Seen from the side (figs. 5, 9) the cells lie so that two are separated, while two are in contact; these latter are the posterior dorsal and the anterior ventral cells, as shown by the succession of the cleavage planes of the fragment. Precisely as in the normal 8-celled embryo, there is an anterior shifting of the dorsal cells upon the lower cells. According as this shifting is to the right or left, in lateral view, one is confronted by a right or left half-embryo. From a comparison of the figures, it is seen that the embryo in fig. 5 is the same as the half turned toward the observer of fig. 1; while that shown in fig. 9 is derived from a right $\frac{1}{2}$ blastomere. The appearance of the $\frac{4}{8}$ embryo in end view is shown in fig. 14, and a characteristic crossing of the spindle axes is exhibited, which is similar to their crossing in the complete egg (vide Castle for figures). The four-celled fragment, then, is in nowise a counterpart of the normal four-celled embryo, but, on the contrary, corresponds in *every* particular to the half of an eight-celled embryo.

From Chabry's fig. 106, it appears that a typical $\frac{4}{8}$ stage occurs also in *Ascidiella.*

$\frac{8}{16}$. At the next cleavage, all the cells divide (figs. 6, 10). Exactly as in the origin of corresponding normal cells, (fig. 2) the *anterior* products of the *anterior* cells (fig. 6 : $B^{5.1}$, $b^{5.3}$; figs. 10 and 16: $A^{5.1}$, $a^{5.3}$) lie slightly below the other cells; and the *posterior* products of the *posterior* cells (fig. 6 : $C^{5.2}$, $c^{5.4}$; figs 10 and 16: $D^{5.2}$, $d^{5.4}$) lie slightly above the median products. On a comparison of fig. 6 and fig. 2, it will be seen, however, that the topographical relations of the cells of the fragment are quite different from the normal. For example in fig. 6, the cell $c^{5.4}$ is in contact with $B^{5.1}$ and $b^{5.3}$, while in the normal egg it lies at the other end of the embryo. A similar rearrangement is still better shown in fig. 10, that of a right $\frac{8}{16}$ embryo, where $D^{5.2}$ is in contact with $A^{5.1}$, while $d^{5.4}$ is in contact with $A^{5.1}$ and $a^{5.3}$. This rearrangement is obviously rendered possible by the absence of the other half of the embryo, so that the cells cohere in a spherical form just as a corresponding number of soap-bubbles. It cannot be considered as a "gliding," for the spindle-axes are from the first accommodated to the changed conditions. That is (figs. 15, 16), the anterior end of the anterior spindles, and the posterior ends of the posterior mitotic figures are swung somewhat toward the original first cleavage-plane of the embryo.

Chabry's fig. 113 leaves no doubt that the $\frac{8}{16}$ embryo of *Ascidiella* is precisely the same as that described above for *Molgula.* From Driesch's fig. 5, there is no doubt that in *Phallusia* the eight cells are arranged as the normal 8 cells.

$\frac{8}{16}-\frac{12}{24}$. When activity is again resumed, only the four lower cells are affected, while the dorsal cells remain quiescent. A 12-celled fragment results (figs. 7 and 11), which is exactly equivalent to a half of the normal 24-cell stage (fig. 3). The quiescence of the dorsal cells during the division of the ventral cells is the first indication of the alternation of activity in the rhythm of cleavage, which was found to be characteristic of this type of segmentation. As in the preceding stage, when the resting condition is assumed, there is a passive rearrangement of the cells. For example, the cells $A^{6.3}$ and $A^{6.4}$ were segmented along an axis inclined at an angle of 45° to the axis joining their centres at the resting stage. Again the cells $D^{6.3}$ and $D^{6.4}$ have retreated around the posterior end of the fragment.

$\frac{16}{32}$. While the eight cells of the lower hemisphere are resting, the four dorsal cells likewise pass into the sixth generation, and a $\frac{16}{32}$ stage results (figs. 8, 12). Its resemblance to the half of a normal 32-cell stage is still less marked than that of a $\frac{12}{24}$ embryo to a half of the normal 24-celled stage. This is so, for the reason that further passive rearrangements of the cells occur, obscuring the partial character of their origin, and causing the cell complex in its solid, or "complete," condition to resemble a normal or "complete" embryo. Nevertheless, the succession of rhythmic cleavages, relation of successive cleavage-planes, etc., point to the operation of factors which are counterparts of those operating in a *half* of the normal embryo.

Later development. The embryo is now "complete," and gives rise to a complete blastula and larva. Although the process of gastrulation has not been carefully observed, enough of the later development has been ascertained to prove that a larva arises which resembles the normal larva, except as regards its smaller size and certain minor defects. My results, therefore, are entirely confirmatory of those of Driesch upon *Phallusia.*

C.—*Cleavage of the $\frac{1}{4}$ blastomeres.*—One of the isolated blastomeres of the four-cell stage, is divided at the next cleavage by a plane which is seen to be at right angles to both of the preceding planes. Therefore it corresponds to the third cleavage plane of the normal embryo. The $\frac{2}{8}$ stage is shown in fig. 17. A subsequent cleavage cuts each of the cells equally, and a $\frac{4}{16}$ stage results (figs. 18, 19), until this time, one is left in doubt as to the true nature of the fragment, that is, whether it will segment as a quarter or as an entire egg. However, from this time on, the character of cleavage is exactly that of a quadrant of a normal embryo.

When division next occurs, only the two cells toward the observer segment (fig. 20), and a stage of six cells results, which is evidently comparable to a $\frac{6}{24}$ embryo only, and not to any stage of the normal development. After a normal period, the dorsal cells (lower in the figure) pass into the sixth generation, and an $\frac{8}{32}$ embryo (fig. 21) is the result. As in the previously described fragments, passive rearrangements occur when the resting condition is assumed, and the cells flatten down upon one another (fig. 22). The cells of the ventral half segment at the next period of activity (fig. 23), while the dorsal cells remain undivided. The resulting $\frac{12}{48}$ stage, although solid, is nevertheless derived from the $\frac{1}{4}$ blastomere through a segmentation of a partial character. This partial character is expressed chiefly in the characteristic rhythm of cleavage.

Concerning the later stages, the results of Driesch are again confirmed. The young larvæ represented in Figs. 25, 26 of this paper illustrate one point further, although of minor consequence. It will be seen that the long axis of the ¼ larva in fig. 25, and the long axes of the ¼ larvæ derived from the same egg, in fig. 26, are approximately parallel to the principal dorso-ventral-axis of the original egg.

SUMMARY AND CONCLUSION.

An isolated blastomere of the Molgula egg segments as if still forming a corresponding part of an entire embryo. The *cleavage phenomena* are strictly *partial*, as regards the origin of cells, the inclination of cleavage-planes, and especially in respect to the rhythm of segmentation. The general appearance of the fragment differs materially from that of a half of a complete embryo, for the reason that rearrangements of the blastomeres occur, which tend progressively to mask the partial nature of development. The end result is a larva of less than normal size, and with defects in certain of its systems. These defects are undoubtedly due to the fact that but a portion of the normal amount of material is available for the formation of the larva; that, for instance, the chorda of a larva derived from a one-half blastomere, receives but one-half of the normal number of cells, and consequently a chorda of one row, and not two rows of cells, results.

In conclusion, one is constrained to adopt the view of Roux-namely, that in Molgula as in the well-known case of the echinoderms (Driesch, Wilson, and others) the development begins as a partial one, but that the missing part is gradually supplied by the cells already present. Driesch is also entirely correct, as far as the end result, a nearly complete larva, is concerned.

EXPLANATION OF PLATE IV.

Magnification of figs. 1–3 about 280 diameters; of all other figures, 250 diameters. The arrows show the direction of cleavage.

Fig. 1, 8-cell stage of *Ciona* from Castle (fig. 23), from the left side.

Fig. 2, 16-cell stage of *Ciona* from Castle (fig. 24), from the left side.

Fig. 3, 24-cell stage of *Ciona* from Castle (fig. 43), from the right side.

Figs. 4–8, cleavage of the left ½ blastomere of *Molgula*, from the side.

Fig. 4, $\frac{2}{4}$ embryo.

Fig. 5, $\frac{4}{8}$ embryo.

Fig. 6, $\frac{8}{16}$ embryo.
Fig. 7, passage to $\frac{12}{24}$ embryo.
Fig. 8, $\frac{16}{32}$ embryo.
Figs. 9–12, cleavage of the right ½ blastomere, from the side.
Fig. 9, $\frac{4}{8}$ embryo.
Fig. 10, $\frac{8}{16}$ embryo.
Fig. 11, $\frac{12}{24}$ embryo.
Fig. 12, $\frac{16}{32}$ embryo.
Figs. 13–16, cleavage of the right ½ blastomere, from the front.
Fig. 13, $\frac{2}{4}$ embryo.
Fig. 14, $\frac{4}{8}$ embryo.
Fig. 15, passage to $\frac{8}{16}$ embryo.
Fig. 16, complete $\frac{8}{16}$ embryo.

EXPLANATION OF PLATE V.

Figs. 17–24, cleavage of the ¼ blastomere, ventral view.
Fig. 17, $\frac{2}{8}$ embryo.
Fig. 18, passage to $\frac{4}{16}$.
Fig. 19, complete $\frac{4}{16}$.
Fig. 20, $\frac{6}{24}$ embryo.
Fig. 21, $\frac{8}{32}$ embryo, immediately after division.
Fig. 22, $\frac{8}{32}$ embryo, in resting condition.
Fig. 23, passage to $\frac{12}{48}$ stage.
Fig. 24, complete $\frac{12}{48}$ embryo.
Fig. 25, ¼ larva. The arrow indicates the long axis.
Fig. 26, two ¼ larvæ, from same egg. The arrows indicate the principal axes.

III.—*The Rutherfurd Photographic Measures of Sixty-five Stars near 61 Cygni.*

BY HERMAN S. DAVIS.

Read May, 1897.

1. It was but natural that Mr. Rutherfurd, in developing the art of astronomical photography, should try his skill upon that star which has attracted the attention of so many investigators ever since Bessel proved by it the possibility of determining stellar parallax.

Of these photographs of *61 Cygni* and its surrounding stars taken by Mr. Rutherfurd, nineteen, exposed between 1871, Nov. 9, and 1874, June 13, were measured by Miss Ida Martin more than twenty years ago, but have remained unreduced until recently placed in my hands for that purpose by Professor J. K. Rees, Director of the Observatory. The present paper contains the results of measures of position of stars surrounding *61 Cygni*, and will be followed by a second paper containing the results of an investigation of the *Parallax of* 61^1 *Cygni.* The methods of reduction used so far as measures of distance are concerned are those presented by Dr. Harold Jacoby in earlier *Contributions* from this Observatory.

2. In Table I are given the general data of exposure of the plates, including the computed values of the zenith-distance, parallactic angle and refraction factor.

3. Table II contains the *means* of the refractions computed for the Eastern and Western impressions from the data of Table I by the formulæ

$$\frac{\sigma - s}{s} = \kappa\,[\tan^2\zeta\cos^2(p - q) + 1]$$

$$\pi - p = -\tfrac{1}{2}\kappa\,\text{cosec}\,1''\tan^2\zeta\sin 2(p - q).$$

The argument for entering this table is p.

4. Table III.—The corrections to the position-angle due to precession, nutation and aberration will be found in column two. These were computed by the formulæ

$$\alpha' = 20.''06 \sin \alpha \sec \delta \qquad \gamma' = \cos \alpha \tan \delta$$
$$\beta' = \cos \alpha \sec \delta \qquad \delta' = \sin \alpha \tan \delta$$
$$\Delta p = (T - t)\,\alpha' - A\alpha' - B\beta' - C\gamma' - D\delta'.$$

The epoch $T = 1873.0$ has been selected to which to reduce all the observations. The substitution of the coördinates of *61¹ Cygni* for this epoch gives:

$$\begin{aligned}
\Delta p_{71} &= -36'' + [1.254]\,A + [9.956_n]\,B + [9.746_n]\,C + [9.742]\,D.\\
\Delta p_{72} &= -18 + [1.254]\,A + [9.956_n]\,B + [9.746_n]\,C + [9.742]\,D.\\
\Delta p_{73} &= 0 + [1.254]\,A + [9.956_n]\,B + [9.746_n]\,C + [9.742]\,D.\\
\Delta p_{74} &= +18 + [1.254]\,A + [9.956_n]\,B + [9.746_n]\,C + [9.742]\,D.
\end{aligned}$$

Where Δp_{71} denotes the correction to be applied to the position-angle for the plates made in 1871, and so on in the other years as denoted by the subscripts.

5. Precession and nutation have no effect upon the distances; but aberration does have, and its amount is given by:

$$\begin{aligned}
\gamma'' &= (\tan \epsilon \sin \delta + \sin \alpha \cos \delta) \sin 1''\\
\delta'' &= -\cos \alpha \cos \delta \sin 1''\\
\Delta s &= (C\gamma'' + D\delta'')\,s
\end{aligned}$$

For *61¹ Cygni* this becomes

$$\Delta s = \{[4.141_n]C + [4.433_n]\,D\}\,s \qquad \text{for all years,}$$

and is additive to the distances to reduce them to 1873.0. This factor of s is given in column three of Table III.

6. The logarithms of the Besselian day-numbers, taken from the *American Ephemeris*, are:

Plates.	log A.	log B.	log C.	log D.
1,	9.692	0.035_n	1.104	1.178
2, 3,	9.699	0.022_n	1.077	1.198
4,	9.774	0.583_n	0.840	1.279
5, 6,	9.816	0.580_n	0.244	1.309
7,	9.821	0.582_n	0.038	1.310
8, 9,	9.788	0.807_n	1.043	1.218
10,	9.800	0.802_n	0.985	1.244
11, 12, 13,	9.805	0.801_n	0.958	1.253
15,	9.336	0.857_n	0.776_n	1.287_n
16, 17,	9.411	0.854_n	0.418_n	1.306_n
18, 19, 20.	9.417	0.854_n	0.364_n	1.307_n

7. In the second portion of Table III. is given the mean of the

East and West zero-corrections computed for each by the formula [*]

$$v = \tfrac{1}{2} k z \tan \delta - y + x$$

in which v is the zero-correction to be added to all observed position angles of each plate.

In the next column are the special corrections [†] required by the position-angles of the Western impressions in consequence of using the same zero-point in measuring both Eastern and Western impressions.[‡] The sum of these two columns is then given in column six, which, therefore, contains the final correction as actually applied in the reductions.

8. In Table IV. is given the tangent correction. This is always negative and its unit is .0001 divisions of the micrometer. It has been computed by the formula:

$$\text{Correction} = -\tfrac{1}{3} s^3 d^2 \sin^2 1'' = [1.7887_n]\, s^3$$

where s denotes the distance in divisions of the glass scale and d is the value of one division of the scale in seconds of arc.

TABLE V.—Measures of Distance.

9. The first column contains the numbers of the stars in order of right ascension and also in parentheses, for convenience of reference to the original measures and plates, are the numbers as assigned by RUTHERFURD. The number of the plate is given in column two, after which follows the *observed* distances for the Eastern and Western impressions. The numbers set down are the fractional part of the measured distance expressed in divisions of the glass scale, the whole number of divisions being ordinarily the same as that given in the *final corrected distance.* Where there is a change of .8 or .9 in the observed distance, it is an indication of a change of a unit in the whole number of divisions in passing from the observed distance to the corrected mean. In columns five, six and seven are placed the corrections as applied for refraction,[§] aberration[||] and scale[¶] respectively; these, with addition of the tangent correction only—which may be obtained directly from Table IV, being practically constant for each star—present all the corrections which have been applied to the observed *mean* distance of the East and West impressions to get the *corrected mean* of column eight.

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[*] Annals N. Y. Acad. of Sci., Vol. VI., p. 272.

[†] Ibid., p. 278.

[‡] Ibid., p. 240.

[§] Table II and Paragraph 2.

[||] Table III and Paragraph 4.

[¶] *Pleiades*, pp. 242–251.

10. It is noticeable that among these corrected means the distances belonging to some of the plates are always larger than the average and to other plates always smaller. To get rid of this variation of scale value, whatever may be its cause, I have selected the following four stars as standards:

No.	Distance.	sin p.	cos p.
5	77.2926	—0.998	+0.054
23	89.2118	—0.068	+0.998
32	77.0019	+0.127	—0.992
48	50.7333	+0.962	—0.274
Sums	294.2396	+0.02	—0.21

Now, if s_5, s_{23}, s_{32}, s_{48} represent the distances of stars 5, 23, 32 and 48 from *61*^{1} *Cygni* on any given plate and Σs_s the sum of the standard distances, there must be added to every distance on that plate for any other star its proportional part of the difference between the mean of the sums of the distances of the standard stars and their separate sums for that particular plate, or:

$$\text{Scale variation} = \frac{\Sigma s_s - (s_5 + s_{23} + s_{32} + s_{48})}{\Sigma s_s}\, s$$

The following table gives the value of this coefficient of s for each plate. The individual values of *scale variation* are given in column nine of Table V.

Plate.	Scale Variation Factor × 10³.
1	+ .1948
2	+ .2275
3	+ .1666
4	— .0027
5	+ .0439
6	+ .0894
7	+ .0928
8	— .1272
9	— .0442
10	— .0408
11	— .0714
12	— .0598
13	— .0129
15	— .1047
16	— .0670
17	— .0714
18	— .0537
19	— .0326
20	— .1241

11. The measures of distance are next to be corrected for the proper motion of the central star. For this purpose let:

$t =$ date of the plate.
$\tau = t - 1873.0$
$\rho =$ annual motion on great circle
$\chi =$ position-angle of that great circle
$S_1 = \cos(\chi - p)$
$S_2 = -\frac{1}{2s}\sin^2(\chi - p)$
$P_1 = \tau\rho$
$P_2 = \tau^2\rho^2$

The correction for proper motion, additive to observed distances, will then be:

$$\Delta s = S_1 P_1 + S_2 P_2$$

I have adopted AUWERS's values of

$\mu = +0^{s}.3444$, $\mu' = +3''.230$,

as given in the *Fundamental Catalog*. Corresponding to these are:

$\rho = 5''.1904 = 0^{d}.18528$, $\chi = 51^{\circ}\,30'\,56''$

The values of p used in the above formulæ were the means after correction for "zero" and refraction, as explained in paragraph 7; and the values of s were after correction for scale variation.

12. The values of S_1 and S_2 will be found in columns two and three of Table VII. The following table gives τ, P_1, and P_2:

Plate.	τ	For Proper Motion.	
		P_1	P_2
1	— 1.142	— 0.2116	+ 0.045
2	— 1.134	— 0.2101	+ 0.044
3	— 1.134	— 0.2101	+ 0.044
4	— 0.085	— 0.0157	+ 0.000
5	— 0.041	— 0.0076	+ 0.000
6	— 0.041	— 0.0076	+ 0.000
7	— 0.036	— 0.0067	+ 0.000
8	+ 0.876	+ 0.1623	+ 0.026
9	+ 0.876	+ 0.1623	+ 0.026
10	+ 0.890	+ 0.1649	+ 0.027
11	+ 0.895	+ 0.1658	+ 0.027
12	+ 0.895	+ 0.1658	+ 0.027
13	+ 0.895	+ 0.1658	+ 0.027
15	+ 1.418	+ 0.2627	+ 0.069
16	+ 1.448	+ 0.2683	+ 0.072
17	+ 1.448	+ 0.2683	+ 0.072
18	+ 1.451	+ 0.2688	+ 0.072
19	+ 1.451	+ 0.2688	+ 0.072
20	+ 1.451	+ 0.2688	+ 0.072

13. As the quantity which depends on the square of the time is always small for a star having even so large a proper motion as *61 Cygni*, its values may be tabulated for limiting values of S_2. Such a table as used in the present paper is:

Plates $S_2 P_2$	1	2 3	4 5 6 7	8 9	10 11 12 13	15	16 17 18 19 20
— .0000	.0	.0	.0	.0	.0	.0	.0
— 1	11.2	11.3	140.0	19.0	18.2	7.2	6.9
— 2	33.5	34.0		57.0	54.8	21.7	20.7
— 3	55.8	56.7		95.0	91.2	36.2	34.7
— 4	78.2	79.3		133.1	127.8	50.7	48.5
— 5	100.5	102.0			164.2	65.2	62.4
— 6	122.8	124.6			200.8	79.7	76.2
— 7	145.1	147.3				94.2	90.1
— 8						108.7	104.0
— 8						123.2	117.8
— .0009						137.7	131.7

The figures at the tops of the columns are the numbers of the plates to which the columns are applicable as determined by their values of P_2. Selecting, therefore, the proper column and using S_2 as the argument in the body of the table (where it is expressed in units of the fourth decimal place), one will find in the first column the desired value of $S_2 P_2$, expressed in divisions of the scale. Column ten of Table V gives the total proper motion correction.

14. A correction for parallax of the principal star was next applied. Using AUWERS's values of the coördinates of *61¹ Cygni* reduced to 1873.0

$$\alpha = 21^{h}\ 01^{m}\ 12.^{s}329$$
$$\delta = 38^{\circ}\ 07'\ 33.''40$$

and the almanac values of r and $\odot$, the radius vector and longitude of the sun respectively. the values of S_3, S_4, P_3 and P_4 were computed by the formulæ

$$g \sin G = \sin \delta \cos \alpha \qquad h \sin H = \sin \delta \sin \alpha$$
$$g \cos G = \sin \alpha \qquad h \cos H = -\cos \delta$$

$$f \sin F = h \sin (H + \varepsilon)$$
$$f \cos F = -\cos \alpha \cos \varepsilon$$

$$S_3 = f \sin (p + F)$$
$$S_4 = g \sin (p + G)$$

$$P_3 = -r \sin \odot$$
$$P_4 = -r \cos \odot$$

The value of p used here was the mean of the position-angles after correction for proper motion and orientation variation, as described in paragraphs 17 and 19. The values of P_3 and P_4 are:

Plates.	For Parallax.	
	P_3	P_4
1	+ 0.727	+ 0.672
2	+ 0.761	+ 0.632
3	+ 0.761	+ 0.632
4	+ 0.915	+ 0.366
5	+ 0.979	+ 0.096
6	+ 0.979	+ 0.095
7	+ 0.982	+ 0.061
8	+ 0.798	+ 0.583
9	+ 0.798	+ 0.583
10	+ 0.845	+ 0.511
11	+ 0.862	+ 0.481
12	+ 0.862	+ 0.480
13	+ 0.862	+ 0.480
15	— 0.962	— 0.322
16	— 1.006	— 0.142
17	— 1.006	— 0.142
18	— 1.008	— 0.125
19	— 1.008	— 0.125
20	— 1.008	— 0.125

In Table VIII, columns two and three, will be found S_3 and S_4. The *coefficient* of the parallax, as printed in column eleven of Table V is

$$S_3P_3 + S_4P_4$$

and the correction, additive to the distances, is

$$(S_3P_3 + S_4P_4)\,\frac{\Pi}{28.''0124}$$

where Π is the parallax expressed in seconds of arc. Table XI gives values of this quantity corresponding to limiting values of the coefficient. The method of using this table is the same as described in paragraph 13. In its construction I used*

$$\Pi = + 0.''3597$$

15. The distances thus corrected for all known disturbances affecting the central star, *61*^{1} *Cygni*, are given in column twelve of Table V. In this column are also the *means* of the distances.

TABLE VI.—**Measures of Position-angle.**

16. This table has been put on pages opposite the corresponding measures of distance in Table V. The first column is a repetition of the number of the plate. In columns two and three are given the *observed* angles for the eastern and western impressions. The number of degrees for the *west* column are the same as printed in the *east* column, except where there is an obvious change of ± 1° indicated by a difference of nearly 60′ in the minutes of the two columns.

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* **The Parallax of *61*^{1} *Cygni* as deduced from Rutherfurd Photographic Measures, by Herman S. Davis.** *Contribution No. 13.*

In column four are placed the zero-corrections of paragraph 7 plus the special corrections due to the precession, etc., mentioned in the same paragraph. This quantity is taken from the last column of Table III. The correction for refraction from Table II is in column five. The mean of the east and west impressions thus corrected is placed in column six.

17. In column seven of Table VI is the correction due to proper motion of the central star. This has been computed from the following formulæ: *

Let t, τ, S_1, P_1, P_2, ρ and χ have the same meaning as in paragraph 11; also let

$$
\begin{aligned}
S_5 &= \sin(\chi - p)\\
S_6 &= \frac{1}{\sigma}\\
S_7 &= S_5\, S_6\\
P_5 &= \tau\rho \operatorname{cosec} 1''\\
K &= -\left\{P_1 \sin\chi \tan\delta + \tfrac{1}{2} P_2 \sin 1'' \sin\chi \cos\chi\,(1 + 2\tan^2\delta)\right\}
\end{aligned}
$$

Then will the correction for proper motion, additive to observed angles, be

$$\Delta p = S_7 P_5\,(1 + S_1 P_1 \cdot S_6) + K.$$

Throughout these formulæ ρ and σ are to be expressed in divisions of the scale, whereas K and Δp are in seconds of arc. The convenience of expressing Δp in this form is more noticeable when it is remembered that $S_1 P_1$ has already been computed for use in correcting the distances; see paragraph 11. Here σ is to represent the value of s after being corrected for scale variation and proper motion.

18. As K is obviously a constant for all stars on the same plate, being only that part of the variation in $(\chi - p)$ due to the effect of meridian-convergence upon the value of χ at different dates, we have for *61¹ Cygni:*

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* Handbuch der Vermessungskunde von Dr. W. Jordan, Bd. III. S. 359. Vierte Auflage.

$$K = -17.''2094\ P_1$$

the term in P_2 being neglected, as its maximum value in the present research is only $\pm 0.''00015$.

The following table gives K for the various plates, and also the values of P_5; while in columns four, five and six of Table VII will be found S_5, S_6 and S_7.

Plate.	For Proper Motion.	
	K	P_5
1	+ 3.″6	− 43644.
2	+ 3.6	− 43338.
3	+ 3.6	− 43338.
4	+ 0.3	− 3248.
5	+ 0.1	− 1567.
6	+ 0.1	− 1567.
7	+ 0.1	− 1376.
8	− 2.8	+ 33478.
9	− 2.8	+ 33478.
10	− 2.8	+ 34013.
11	− 2.8	+ 34204.
12	− 2.8	+ 34204.
13	− 2.8	+ 34204.
15	− 4 5	+ 54191.
16	− 4.6	+ 55338.
17	− 4.6	+ 55338.
18	− 4.6	+ 55452.
19	− 4.6	+ 55452.
20	− 4.6	+ 55452.

19. *Orientation Variation.*—When the angles have been corrected as described above, observation of the *corrected mean* plus *proper motion* in Table VI reveals a variation of measures on some of the plates from the mean of all that is erratic, and in some cases very considerable in magnitude. This is undoubtedly due to the method which RUTHERFURD used for the orientation of his plates.

It was his custom in making the exposures to take two impressions of the stars on each plate. After the second, or western impression, the telescope clock was stopped, and the stars were allowed to trail across the plate for a distance of sixty to eighty scale-divisions. The clock was then again made to run long enough to permit the formation of another image of the central star. The line joining this last image with the central image was used as the origin of the position-angles. Angles so measured were made in the present paper to conform to the custom of counting from the north point towards the east by addition of 270° to the observed readings, as seen in Table VI.

Of course the position-angle of this last impression of the principal star is not exactly 270°, however, unless there has been absolutely no shifting of the telescope in declination during the formation of the trail, or when clamping in the clock for the final image. It is *a priori* probable that such shifting did occur; but with such alterations in the balance-weights of the tube, in the pointing of the telescope, and in the other conditions of exposure of many plates during the course of several years, we may fairly assume, on the other hand, that such shifting in declination is not systematically in the same direction; that, consequently, the mean of the position-angles of a given star as determined from all the plates is its most probable value. Hence, if all the stars were found on all the plates, it would be unnecessary to apply a correction for error of orientation. But such is not the case. Furthermore it is desirable to use the individual measures separately for a determination of the parallax.

This correction may be deduced from standard stars by taking from the mean of all the angles of all the plates the angle measured on each plate separately, and regarding the residual as the orientation variation of that plate. For any particular star such residuals would not, however, be the true correction; for it would contain the effect of both the proper motion and the parallax of the central star. Several stars should, therefore, be selected as standards; and they should be so distributed in distance and angle as to eliminate both parallax and proper motion from the mean of their residuals for each plate severally. Since the probable error of measures of angle vary inversely as the distance, these means should be taken by weight proportional to the square of the distance.

Expressed symbolically these conditions are:

A. $$\frac{\Sigma\sigma^2 S_8}{\Sigma\sigma^2} = 0 \quad \text{and} \quad \frac{\Sigma\sigma^2 S_9}{\Sigma\sigma^2} = 0$$

B. $$\Sigma S_7 = 0.$$

The significance of S_8 and S_9 will be found in paragraph 22, and of S_7 in paragraph 17.

20. It is easily seen that both A and B cannot be satisfied at the same time, unless the direction of proper motion of the principal star coincide with the major or the minor axis of the parallactic ellipse. This fortunately is very nearly the case with *61^1 Cygni;* wherefore it would have been immaterial here whether the angles of the standard stars had been corrected for proper motion or not, though as a matter of fact they were so corrected; as would ordinarily be necessary.

21. If stars can be found on all the plates which will satisfy only very closely, but not exactly, condition A, the *residuum* of the parallactic effect may be more nearly eliminated by adding to the orientation variation deduced from such stars the quantity

$$\left\{ \frac{(P_3' - P_3)\,\Sigma\sigma^2 S_8}{\Sigma\sigma^2} + \frac{(P_4' - P_4)\,\Sigma\sigma^2 S_9}{\Sigma\sigma^2} \right\} \Pi'$$

where the primed P_3' and P_4' are the means of the values of P_3 and P_4 for all the plates, and where Π' is an approximate value of the parallax, or a value deduced from the measures of distance.

In this paper the following six stars were selected as the standards:

Star	$\sigma^2 S_8$	$\sigma^2 S_9$	S_7	σ^2
5	—423898.2	+227748.4	+0.008588	5962.
6	— 90170.0	+550938.7	— .000240	9017.
13	—611921.1	—381846.5	+ .009566	9667.
23	—459811.3	—441482.6	+ .009229	7969.
32	+418587.4	+364040.6	— .011118	5929.
48	+322758.0	— 85914.0	— .016022	2580.

These give:

$$\frac{\Sigma\sigma^2 S_8}{\Sigma\sigma^2} = -20.5 \qquad \frac{\Sigma\sigma^2 S_9}{\Sigma\sigma^2} = +5.7 \qquad \Sigma S_7 = -.000003$$

which shows that they are admirably adapted to the present purpose. From these stars, therefore, and with $\Pi' = +0.''40$ have been deduced the following corrections, additive to observed position-angles.

Plate.	Orientation Variation.
	′ ″
1	+0 13
2	+1 0
3	+0 6
4	−0 35
5	−0 8
6	+0 17
7	+3 21
8	−0 12
9	−0 30
10	−0 21
11	−0 31
12	+0 11
13	+0 24
15	−0 19
16	−0 29
17	−2 5
18	−0 50
19	−0 1
20	+0 14

22. In column eight of Table VI are given the parallax coefficients. They have been computed by the formulæ:

$$S_8 P_3 + S_9 P_4$$

where:

$$S_8 = \frac{f \operatorname{cosec} 1''}{28.''0124} \cdot S_6 \cos(\pi + F)$$

$$S_9 = \frac{g \operatorname{cosec} 1''}{28.''0124} S_6 \cos(\pi + G)$$

$$S_6 = \frac{1}{\sigma}$$

and where f, g, F, G, P_3, and P_4 have the same meaning as in paragraph 14. The value of the position-angle used here, π, is the angle p corrected for proper motion and orientation variation. The quantities S_8, S_9, and S_6 are in columns four and five of Table VIII and five of Table VII respectively. P_3 and P_4 are tabulated in paragraph 14.

23. After adding to the observed angle the correction

$$(S_8 P_3 + S_9 P_4)\,\Pi$$

taken from Table XI with the parallax coefficient of column eight, Table VI, as the argument we have the final corrected angle given in the last column of Table VI.

24. Table IX.—Column three contains the mean of the final position-angles of Table VI, and column two the mean of the distances, converted to seconds of arc by the scale value $28.''0124$. These are followed in columns four and five by the differences of right ascension and of declination derived by aid of the formulæ :

Logarithms for Plates of *61¹ Cygni* only.

$$
\begin{array}{lll}
n = \sigma \sin \pi & & \\
m = \sigma \cos \pi & & \\
P = \sec \delta & & = [0.104215] \\
Q = [4.685575\ ] \tan \delta \sec \delta & & = [4.6846\ ] \\
R = [8.89403_n\ ] \tan^2 \delta \sec \delta & & = [8.7878_n\ ] \\
S = [8.89403\ ] \sec \delta\ (1 + 3 \tan^2 \delta) & & = [9.4528\ ] \\
T = [4.384545_n] \tan \delta & & = [4.2793_n\ ] \\
U = [8.59300_n\ ] (1 + 3 \tan^2 \delta) & & = [9.0475_n\ ] \\
V = [3.57960_n\ ] \sec \delta \tan \delta\ (1 + 3 \tan^2 \delta) & & \\
W = [3.57960\ ] \sec \delta \tan \delta\ (2 + 3 \tan^2 \delta) & &
\end{array}
$$

$$
\begin{aligned}
\alpha' - \alpha &= Pn + Qnm + Rn^3 + Snm^2 + (Vn^3m + Wnm^3) \\
\delta' - \delta &= \phantom{Pn + Qnm + {}} m + Tn^2 + Un^2m
\end{aligned}
$$

where σ and π are the final corrected mean distance and position-angle respectively of the star whose α' and δ' are desired. It was found also that the terms in V and W were not needed, since they are so nearly equal and have contrary signs.

In column six is the number of plates on which the image of the star was impressed; though it is proper to state that the given position is the result of at least twenty measures of distance and twelve of position-angle for *each* plate recorded in this column.

In columns seven and eight are the *Durchmusterung* number and magnitude for as many of the stars as could be identified. A few of those found in the *Durchmusterung* but not found on these plates, though of much brighter magnitude than many which are on the plates, no doubt are missing because of their color; as obviously light from reddish stars affects the plate but little, though optically it may appear quite bright.

25. Table X is on pages opposing Table IX and gives the right ascensions and declinations of each star. These were obtained by adding the $\alpha' - \alpha$, $\delta' - \delta$ of Table X to AUWERS's position of *61¹ Cygni* reduced to 1873.0 with the constants given in the *Fundamental Catalog :*

$$
\left.
\begin{array}{l}
\alpha = 21^{\mathrm{h}}\ 01^{\mathrm{m}}\ 12^{\mathrm{s}}.329 \\
\delta = 38^{\circ}\ 07'\ 33''.40
\end{array}
\right\}\ 1873.0
$$

The other columns contain the precession constants, whereby the positions of these stars may be reduced to another epoch, T, by the formulæ :

$$\alpha_T = \alpha_{1873} + J(T - 1873) + K\frac{(T - 1873)^2}{200}.$$

$$\delta_T = \delta_{1873} + L(T - 1873) + M\frac{(T - 1873)^2}{200}.$$

TABLE I.—GENERAL DATA.—Observatory of L. M. Rutherfurd, New York.

Lat. = 40° 43′ 48″.5 Long. = 4h 55m 56s.62 W

Plate.	Date.		Sidereal Time.	Hour Angle.	Barom	Att. Therm.	Ext. Therm.	Tel. Therm.	Focus.	Zero.	ζ	q	Log. κ
			h m s	h m s		°	°	°			°	°	
1	1871	Nov. 9	0 11 5	3 9 56	29.988	45	42	45	7.7	70.38	36.32	+70.57	6.4559
2		Nov. 12	23 58 5	2 56 56	30.460	38	35	38	7.8	77.08	33.91	+71.38	6.4690
3		Nov. 12	0 28 20	3 27 11	30.460	38	35	40	7.8	77.19	39.50	+69.38	6.4685
4	1872	Nov. 29	0 18 47	3 17 35	29.748	25	22	25	8.0	69.72	37.74	+70.04	6.4706
5		Dec. 15	0 14 47	3 13 35	30.150	35	34	35	7.9	63.56	37.01	+70.31	6.4654
6		Dec. 15	1 21 2	4 19 50	30.150	35	34	35	7.8	63.18	49.07	+65.33	6.4641
7		Dec. 17	0 45 52	3 44 40	30.328	33	32	33	7.9	69.44	42.71	+68.10	6.4695
8	1873	Nov. 15	0 28 20	3 27 7	29.716	35	35	35	8.0	70.05	39.50	+69.38	6.4581
9		Nov. 15	1 8 12	4 6 59	29.716	35	35	35	7.9	76.95	46.76	+66.40	6.4574
10		Nov. 20	23 26 2	2 24 49	30.070	32	30	32	7.9	71.01	27.88	+73.13	6.4682
11		Nov. 22	23 5 47	2 4 34	30.392	38	37	40	7.8	77.15	24.10	+73.95	6.4667
12		Nov. 22	23 47 2	2 45 48	30.392	38	37	40	7.8	84.37	31.82	+72.05	6.4663
13		Nov. 22	0 24 47	3 23 33	30.392	38	37	40	7.8	70.29	38.83	+69.67	6.4660
15	1874	June 1	18 12 47	21 11 30	29.984	60	55	60	7.7	68.32	32.33	—71.88	6.4442
16		June 12	16 49 32	19 48 15	29.950	71	69	70	7.64	(63.00)	47.64	—66.03	6.4303
17		June 12	17 19 22	20 18 5	29.950	71	69	70	7.64	63.18	42.20	—68.33	6.4312
18		June 13	16 59 2	19 57 45	30.300	59	57	60	7.7	(62.88)	45.90	—66.77	6.4461
19		June 13	17 29 32	20 28 15	30.300	59	57	60	7.7	63.67	40.34	—69.07	6.4466
20		June 13	18 3 2	21 1 45	30.300	59	57	60	7.7	70.22	34.14	—71.30	6.4472

TABLE II.—CORRECTIONS FOR REFRACTION.

Position Angle, p.		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$	Position Angle, p.		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$
PLATE 1.				PLATE 2.			
			″				″
71°	251°	+.440	0.0	71°	251°	+.427	0.0
81	261	.436	− 5.4	81	261	.423	− 4.7
91	271	.422	−10.2	91	271	.411	− 8.8
101	281	.402	−13.8	101	281	.394	−11.9
111	291	.377	−15.7	111	291	.372	−13.5
121	301	.350	−15.7	121	301	.349	−13.5
131	311	.325	−13.8	131	311	.327	−11.9
141	321	.304	−10.2	141	321	.310	− 8.8
151	331	.291	− 5.4	151	331	.298	− 4.7
161	341	.286	0.0	161	341	.294	0.0
171	351	.291	+ 5.4	171	351	.298	+ 4.7
181	1	.304	+10.2	181	1	.310	+ 8.8
191	11	.325	+13.8	191	11	.327	+11.9
201	21	.350	+15.7	201	21	.349	+13.5
211	31	.377	+15.7	211	31	.372	+13.5
221	41	.402	+13.8	221	41	.394	+11.9
231	51	.422	+10.2	231	51	.411	+ 8.8
241	61	.436	+ 5.4	241	61	.423	+ 4.7
251	71	+.440	0.0	251	71	+.427	0.0
PLATE 3.				PLATE 4.			
			″				″
69°	249°	+.494	0.0	70°	250°	+.473	0.0
79	259	.488	− 7.0	80	260	.468	− 6.3
89	269	.471	−13.2	90	270	.453	−11.8
99	279	.444	−17.8	100	280	.429	−15.8
109	289	.411	−20.3	110	290	.400	−18.0
119	299	.377	−20.3	120	300	.369	−18.0
129	309	.344	−17.8	130	310	.340	−15.8
139	319	.318	−13.2	140	320	.317	−11.8
149	329	.300	− 7.0	150	330	.301	− 6.3
159	339	.294	0.0	160	340	.296	0.0
169	349	.300	+ 7.0	170	350	.301	+ 6.3
179	359	.318	+13.2	180	0	.317	+11.8
189	9	.344	+17.8	190	10	.340	+15.8
199	19	.377	+20.3	200	20	.369	+18.0
209	29	.411	+20.3	210	30	.400	+18.0
219	39	.444	+17.8	220	40	.429	+15.8
229	49	.471	+13.2	230	50	.453	+11.8
239	59	.488	+ 7.0	240	60	.468	+ 6.3
249	69	+.494	0.0	250	70	+.473	0.0

TABLE II.—CORRECTIONS FOR REFRACTION. (*Continued.*)

Position Angle, p.		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$	Position Angle, p.		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$
PLATE 5.				PLATE 6.			
70°	250°	+.458	″ 0.0	65°	245°	+.678	″ 0.0
80	260	.453	— 5.8	75	255	.666	—13.6
90	270	.439	—11.0	85	265	.633	—25.7
100	280	.417	—14.8	95	275	.581	—34.6
110	290	.390	—16.8	105	285	.518	—39.3
120	300	.361	—16.8	115	295	.451	—39.3
130	310	.333	—14.8	125	305	.388	—34.6
140	320	.312	—11.0	135	315	.336	—25.7
150	330	.297	— 5.8	145	325	.303	—13.6
160	340	.292	0.0	155	335	.291	0.0
170	350	.297	+ 5.8	165	345	.303	+13.6
180	0	.312	+11.0	175	355	.336	+25.7
190	10	.333	+14.8	185	5	.388	+34.6
200	20	.361	+16.8	195	15	.451	+39.3
210	30	.390	+16.8	205	25	.518	+39.3
220	40	.417	+14.8	215	35	.581	+34.6
230	50	.439	+11.0	225	45	.633	+25.7
240	60	.453	+ 5.8	235	55	.666	+13.6
250	70	+.458	0.0	245	65	+.678	0.0
PLATE 7.				PLATE 8.			
68°	248°	+.546	″ 0.0	69°	249°	+.482	″ 0.0
78	258	.539	— 8.9	79	259	.476	— 6.9
88	268	.517	—16.7	89	269	.459	—12.9
98	278	.484	—22.4	99	279	.433	—17.4
108	288	.443	—25.5	109	289	.402	—19.8
118	298	.399	—25.5	119	299	.367	—19.8
128	308	.358	—22.4	129	309	.336	—17.4
138	318	.325	—16.7	139	319	.310	—12.9
148	328	.303	— 8.9	149	329	.293	— 6.9
158	338	.295	0.0	159	339	.287	0.0
168	348	.303	+ 8.9	169	349	.293	+ 6.9
178	358	.325	+16.7	179	359	.310	+12.9
188	8	.358	+22.4	189	9	.336	+17.4
198	18	.399	+25.5	199	19	.367	+19.8
208	28	.443	+25.5	209	29	.402	+19.8
218	38	.484	+22.4	219	39	.433	+17.4
228	48	.517	+16.7	229	49	.459	+12.9
238	58	.539	+ 8.9	239	59	.476	+ 6.9
248	68	+.546	0.0	249	69	+.482	+ 0.0

TABLE II.—CORRECTIONS FOR REFRACTION. (*Continued.*)

Position Angle, p		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$	Position Angle, p		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$
PLATE 9.				PLATE 10.			
			″				″
66°	246°	+.612	0.0	73°	253°	+.376	0.0
76	256	.602	−11.5	83	263	.374	− 2.9
86	266	.574	−21.5	93	273	.367	− 5.5
96	276	.531	−29.0	103	283	.356	− 7.3
106	286	.477	−33.0	113	293	.342	− 8.4
116	296	.421	−33.0	123	303	.328	− 8.4
126	306	.368	−29.0	133	313	.314	− 7.3
136	316	.325	−21.5	143	323	.304	− 5.5
146	326	.297	−11.5	153	333	.296	− 2.9
156	336	.287	0.0	163	343	.294	0.0
166	346	.297	+11.5	173	353	.296	+ 2.9
176	356	.325	+21.5	183	3	.304	+ 5.5
186	6	.368	+29.0	193	13	.314	+ 7.3
196	16	.421	+33.0	203	23	.328	+ 8.4
206	26	.477	+33.0	213	33	.342	+ 8.4
216	36	.531	+29.0	223	43	.356	+ 7.3
226	46	.574	+21.5	233	53	.367	+ 5.5
236	56	.602	+11.5	243	63	.374	+ 2.9
246	66	+.612	0.0	253	73	+.376	0.0
PLATE 11.				PLATE 12.			
			″				″
74°	254°	+.352	0.0	72°	252°	+.406	0.0
84	264	.350	− 2.1	82	262	.403	− 4.0
94	274	.345	− 3.9	92	272	.393	− 7.5
104	284	.337	− 5.2	102	282	.378	−10.0
114	294	.327	− 6.0	112	292	.359	−11.4
124	304	.317	− 6.0	122	302	.339	−11.4
134	314	.308	− 5.2	132	312	.321	−10.0
144	324	.300	− 3.9	142	322	.306	− 7.5
154	334	.295	− 2.1	152	332	.296	− 4.0
164	344	.293	0.0	162	342	.293	0.0
174	354	.295	+ 2.1	172	352	.295	+ 4.0
184	4	.300	+ 3.9	182	2	.306	+ 7.5
194	14	.308	+ 5.2	192	12	.321	+10.0
204	24	.317	+ 6.0	202	22	.339	+11.4
214	34	.327	+ 6.0	212	32	.359	+11.4
224	44	.337	+ 5.2	222	42	.378	+10.0
234	54	.345	+ 3.9	232	52	.393	+ 7.5
244	64	.350	+ 2.1	242	62	.403	+ 4.0
254	74	+.352	0.0	252	72	+.406	0.0

TABLE II. CORRECTIONS FOR REFRACTION. (*Continued.*)

Position Angle, p.		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$	Position Angle, p.		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$
		PLATE 13.				PLATE 14.	
			″				
70°	250°	+.481	0.0				
80	260	.475	− 6.7				
90	270	.459	−12.5				
100	280	.434	−16.9				
110	290	.403	−19.2				
120	300	.370	−19.2				
130	310	.339	−16.9				
140	320	.314	−12.5				
150	330	.298	− 6.7				
160	340	.292	0.0				
170	350	.298	+ 6.7				
180	0	.314	+12.5				
190	10	.339	+16.9				
200	20	.370	+19.2				
210	30	.403	+19.2				
220	40	.434	+16.9				
230	50	.459	+12.5				
240	60	.475	+ 6.7				
250	70	+.481	0.0				
		PLATE 15.				PLATE 16.	
			″				″
288°	108°	+.389	0.0	294°	114	+.593	0.0
298	118	.386	− 3.9	304	124	.583	−11.4
308	128	.376	− 7.4	314	134	.555	−21.5
318	138	.362	−10.0	324	144	.512	−28.9
328	148	.343	−11.3	334	154	.459	−32.9
338	158	.324	−11.3	344	164	.403	−32.9
348	168	.306	−10.0	354	174	.350	−28.9
358	178	.291	− 7.4	4	184	.307	−21.5
8	188	.281	− 3.9	14	194	.279	−11.4
18	198	.278	0.0	24	204	.269	0.0
28	208	.281	+ 3.9	34	214	.279	+11.4
38	218	.291	+ 7.4	44	224	.307	+21.5
48	228	.306	+10.0	54	234	.350	+28.9
58	238	.324	+11.3	64	244	.403	+32.9
68	248	.343	+11.3	74	254	.459	+32.9
78	258	.362	+10.0	84	264	.512	+28.9
88	268	.376	+ 7.4	94	274	.555	+21.5
98	278	.386	+ 3.9	104	284	.583	+11.4
108	288	+.389	0.0	114	294	+.593	0.0

TABLE II.—CORRECTIONS FOR REFRACTIONS. (*Concluded.*)

Position Angle, p.		$\frac{\sigma-s}{s}\times 10^3$	$\pi-p$	Position Angle, p.		$\frac{\sigma-s}{s}\times 10^3$	$\pi-p$
PLATE 17.				PLATE 18.			
			″				″
292°	112°	+.492	0.0	293°	113°	+.576	0.0
302	122	.485	−7.8	303	123	.567	−10.5
312	132	.466	−14.7	313	133	.541	−19.7
322	142	.437	−19.8	323	143	.501	−26.6
332	152	.400	−22.6	333	153	.453	−30.2
342	162	.362	−22.6	343	163	.402	−30.2
352	172	.326	−19.8	353	173	.353	−26.6
2	182	.296	−14.7	3	183	.314	−19.7
12	192	.277	−7.8	13	193	.288	−10.5
22	202	.270	0.0	23	203	.279	0.0
32	212	.277	+7.8	33	213	.288	+10.5
42	222	.296	+14.7	43	223	.314	+19.7
52	232	.326	+19.8	53	233	.353	+26.6
62	242	.362	+22.6	63	243	.402	+30.2
72	252	.400	+22.6	73	253	.453	+30.2
82	262	.437	+19.8	83	263	.501	+26.6
92	272	.466	+14.7	93	273	.541	+19.7
102	282	.485	+7.8	103	283	.567	+10.5
112	292	+.492	0.0	113	293	+.576	0.0
PLATE 19.				PLATE 20.			
			″				″
291°	111°	+.482	0.0	289°	109°	+.409	0.0
301	121	.476	−7.1	299	119	.405	−4.5
311	131	.459	−13.4	309	129	.394	−8.6
321	141	.432	−18.0	319	139	.377	−11.5
331	151	.399	−20.5	329	149	.356	−13.1
341	161	.363	−20.5	339	159	.333	−13.1
351	171	.331	−18.0	349	169	.312	−11.5
1	181	.304	−13.4	359	179	.295	−8.6
11	191	.286	−7.1	9	189	.284	−4.5
21	201	.280	0.0	19	199	.280	0.0
31	211	.286	+7.1	29	209	.284	+4.5
41	221	.304	+13.4	39	219	.295	+8.6
51	231	.331	+18.0	49	229	.312	+11.5
61	241	.363	+20.5	59	239	.333	+13.1
71	251	.399	+20.5	69	249	.356	+13.1
81	261	.432	+18.0	79	259	.377	+11.5
91	271	.459	+13.4	89	269	.394	+8.6
101	281	.476	+7.1	99	279	.405	+4.5
111	291	+.482	0.0	109	289	+.409	0.0

TABLE III.—CORRECTIONS FOR PRECESSION, ETC., TO 1873 AND ZERO CORRECTIONS.

Plate No.	Precession, etc.		Zero Correction ½(East + West)	Special Correction Mean.	Adopted Mean
	Position Angle Correction.	Distance Factor × 10⁸			
	″		′ ″	″	′ ″
1	—25.	—.0584	+12 29	—27	+12 2
2	—24.	—.0593	13 52	—24	13 28
3	—24.	—.0593	13 58	—24	13 34
4	+ 3.	—.0611	13 1	—22	12 39
5	+ 8.	—.0576	11 57	—19	11 38
6	+ 8.	—.0576	12 12	—34	11 38
7	+ 8.	—.0568	13 9	—17	12 52
8	+20.	—.0601	13 23	—20	13 3
9	+20.	—.0601	14 50	—20	14 30
10	+21.	—.0609	13 27	—20	13 7
11	+22.	—.0611	14 34	—21	14 13
12	+22.	—.0611	15 56	—21	15 35
13	+22.	—.0611	13 27	—19	13 8
15	+21.	+.0608	12 45	—32	12 13
16	+19.	+.0584	11 27	—29	10 58
17	+19.	+.0584	11 38	—28	11 10
18	+19.	+.0582	11 29	—26	11 3
19	+19.	+.0582	11 45	—23	11 22
20	+19.	+.0582	+13 3	—25	+12 38

TABLE IV.—TANGENT CORRECTION.

This correction is always *negative*, and is here expressed in terms of the *fourth* decimal place of the micrometer readings.

Distance.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
20.	—0	—0	—0	—0	—0	—1	—1	—1	—1	—1
30.	2	2	2	2	2	3	3	3	3	3
40.	4	4	4	5	5	6	6	6	7	7
50.	8	8	8	9	9	10	10	11	11	12
60.	13	13	14	15	16	17	17	18	19	20
70.	21	22	23	24	25	26	27	28	30	31
80.	32	34	35	36	37	38	40	41	42	43
90.	45	46	48	50	52	53	55	57	59	61
100.	62	64	65	67	69	71	73	75	77	79
110.	81	83	85	87	90	93	95	98	100	103
120.	106	109	112	114	117	120	123	126	129	132
130.	—135	—138	—141	—145	—148	—151	—155	—158	—162	—165

TABLE V.—RESULTS OF MEASURES OF DISTANCE.

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Parallax *Co-efficient.*	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	s				σ
	1	.5188	.5206	479	—79	4	.5452	+262	+.0502	+0.612	134.6295
1	2	.4992	.5242	458	—80	4	.5349	+306	+.0499	+ .582	.6229
	3	.5392	.5166	479	—80	2	.5531	+224	+.0499	+ .582	.6329
(16)	5	.5864	.6211	464	—78	12	.6285	+ 59	+.0018	+ .157	.6382
	6	.5898	.6182	513	—78	5	.6330	+120	+.0018	+ .157	.6488
	7	.6063	.6018	493	—77	10	.6316	+125	+.0016	+ .129	.6474
	10	.6539	.6502	439	—82	10	.6737	— 55	—.0394	+ .490	.6351
	15	.6880	.7412	516	+82	5	.7599	—141	—.0629	— .343	.6785
	16	.5970	.6074	774	+79	6	.6731	— 90	—.0643	— .197	.5973
	17	.6227	.6303	650	+79	6	.6851	— 96	—.0643	— .197	.6087
						Mean					134.6339
	3	.7912	.7799	532	—65	112	.8357	+181	+.2096	+0.925	109.0753
2	11	.2029	.2003	384	—67	117	.2371	— 78	—.1654	+ .970	.0764
	12	.1825	.1745	438	—67	112	.2189	— 65	—.1654	+ .970	.0595
(25)	13	.1650	.1473	517	—67	112	.2045	— 14	—.1654	+ .970	.0502
	15	.2923	.2717	355	+66	106	.3267	—114	—.2621	—1.011	.0402
	19	.3074	.3010	382	+63	112	.3519	— 36	—.2682	—0.991	.0674
						Mean					109.0615
	2	.0674	.0344	474	—68	105	.0930	+260	+.2100	+0.892	114.3405
3	11	.4735	.4343	397	—70	123	.4897	— 82	—.1658	+ .950	.3279
	13	.4314	.4084	533	—70	114	.4685	— 15	—.1658	+ .950	.3134
(26)	15	.5538	.5548	361	+70	105	.5987	—120	—.2626	—1.004	.3112
	18	.5716	.5540	395	+67	107	.6106	— 62	—.2687	—0.997	.3229
						Mean					114 3232
4	2	.5200	.5410	451	—66	114	.5722	+252	+.2094	+0.868	110.8179
	12	.8999	.9155	435	—68	114	.9475	— 66	—.1653	+ .932	.7876
(27)						Mean					110.8028
5	1	.0086	.0100	327	—45	115	.0462	+150	+.1583	+0.934	77.2315
	2	.0038	.0036	320	—46	115	.0398	+175	+.1571	+ .925	.2263
(19)	3	.0032	.0030	360	—46	115	.0432	+128	+.1571	+ .925	.2250
	4	.2026	.1564	350	—47	115	.2185	— 2	+.0117	+ .827	.2406
	5	.1722	.1676	339	—44	115	.2080	+ 34	+.0057	+ .670	.2257
	6	.1544	.1458	463	—44	117	.2009	+ 69	+.0057	+ .670	.2221
	7	.1684	.1552	397	—44	115	.2058	+ 72	+.0050	+ .646	.2263
	8	.3030	.2988	352	—46	115	.3401	— 98	—.1216	+ .912	.2204
	9	.2870	.2860	438	—46	115	.3343	— 34	—.1216	+ .912	.2210
	10	.3072	.2922	289	—47	115	.3325	— 32	—.1235	+ .889	.2172
	11	.3110	.3048	271	—47	115	.3389	— 55	—.1242	+ .877	.2205
	12	.3072	.3017	307	—47	115	.3391	— 46	—.1242	+ .877	.2216
	13	.3002	.2900	355	—47	115	.3345	— 10	—.1242	+ .877	.2206
	15	.3853	.3863	300	+47	117	.4293	— 81	—.1968	— .824	.2138
	16	.3727	.3607	432	+45	116	.4231	— 52	—.2010	— .720	.2077
	17	.3793	.3739	368	+45	116	.4266	— 55	—.2010	— .720	.2109
	18	.3771	.3737	424	+45	116	.4310	— 42	—.2014	— .709	.2163
	19	.3878	.3854	358	+45	116	.4356	— 25	—.2014	— .709	.2226
	20	.3781	.3947	313	+45	116	.4309	— 96	—.2014	— .709	.2108
						Mean					77.2211

TABLE VI.—RESULTS OF MEASURES OF ANGLE.

Plate.	Observed Position Angle.		Zero Correction plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient*.	Final Corrected Angle. π
	East.	West.						
1	37° 37′ 13″	38′ 1″	12′ 2″	—16″	49′ 23″	—5′ 11″	—41	307° 44′ 10″
2	35 58	36 24	13 28	—13	49 26	—5 9	—43	45 2
3	36 36	37 10	13 34	—18	50 9	—5 9	—43	44 51
5	33 34	33 42	11 38	—15	45 1	—0 11	—51	44 24
6	33 2	33 30	11 38	—32	44 22	—0 11	—51	44 10
7	29 2	29 22	12 52	—23	41 41	—0 10	—52	44 33
10	27 3	27 33	13 7	— 8	40 17	+4 3	—46	43 42
15	25 8	25 34	12 13	— 7	37 27	+6 26	+52	43 53
16	26 53	27 27	10 58	—18	37 50	+6 34	+54	44 14
17	28 18	28 40	11 10	—12	39 27	+6 34	+54	44 15
				Mean				307 44 19.4
3	325 11 34	12 22	13 34	+10	25 42	—0 23	+21	235 25 33
11	10 54	11 18	14 13	+ 3	25 22	+0 18	+12	25 13
12	8 2	8 58	15 35	+ 6	24 11	+0 18	+12	24 44
13	11 20	11 12	13 8	+10	24 34	+0 19	+12	25 21
15	12 55	13 37	12 13	+11	25 40	+0 29	— 3	25 49
19	13 8	13 48	11 22	+18	25 8	+0 30	+ 9	25 40
				Mean				235 25 23.3
2	319 54 34	54 28	13 28	+ 9	8 8	+0 13	+26	230 9 30
11	54 45	55 27	14 13	+ 4	9 23	—0 10	+17	8 48
13	55 22	55 25	13 8	+13	8 45	—0 10	+17	9 5
15	57 15	58 12	12 13	+10	10 6	—0 16	— 8	9 28
18	57 48	59 32	11 3	+25	10 8	—0 16	+ 3	9 3
				Mean				230 9 10.8
2	316 42 20	43 42	13 28	+10	56 39	+0 35	+30	226 58 25
12	42 20	43 42	15 35	+ 9	58 45	—0 27	+22	58 37
				Mean				226 58 31.0
1	3 0 28	1 28	12 2	—11	12 49	—6 12	—26	273 6 41
2	2 58 36	59 32	13 28	— 9	12 25	—6 9	—30	7 5
3	59 6	59 40	13 34	—15	12 42	—6 9	—30	6 28
4	55 20	55 48	12 39	—13	8 0	—0 28	—51	6 39
5	55 50	56 35	11 38	—12	7 38	—0 13	—66	6 53
6	55 4	56 52	11 38	—33	7 3	—0 13	—66	6 43
7	50 38	51 27	12 52	—20	3 34	—0 12	—68	6 19
8	49 32	49 50	13 3	—15	2 29	+4 44	—35	6 48
9	48 3	48 53	14 30	—26	2 32	+4 44	—35	6 33
10	48 35	49 33	13 7	— 5	2 6	+4 49	—41	6 19
11	47 56	48 22	14 13	— 4	2 33	+4 50	—43	6 37
12	45 58	46 20	15 35	— 8	1 36	+4 50	—43	6 22
13	48 28	49 23	13 8	—13	1 51	+4 50	—43	6 50
15	46 7	47 10	12 13	+ 6	58 57	+7 40	+56	6 38
16	47 32	47 38	10 58	+23	58 56	+7 49	+66	6 40
17	48 15	49 23	11 10	+13	0 12	+7 49	+66	6 20
18	46 56	47 58	11 3	+20	58 50	+7 50	+67	6 14
19	46 37	47 11	11 22	+12	58 28	+7 50	+67	6 41
20	45 18	45 46	12 38	+ 7	58 17	+7 50	+67	6 45
				Mean				273 6 36.6

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Parallax *Co-efficient.*	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	s				σ
6	1	.6858	.6818	401	—55	131	.7262	+185	+.2115	+0.871	94.9674
	2	.6928	.6910	393	—56	130	.7333	+215	+.2100	+ .892	.9763
(24)	3	.6920	.6812	455	—56	130	.7342	+158	+.2100	+ .892	.9715
	4	.8981	.8831	437	—58	134	.9365	— 3	+.0157	+ .971	.9644
	5	.9014	.8962	423	—55	138	.9441	+ 42	+.0076	+ .962	.9683
	6	.8773	.8578	626	—55	132	.9326	+ 85	+.0076	+ .962	.9611
	7	.8896	.8944	503	—54	138	.9454	+ 88	+.0067	+ .956	.9732
	8	.0688	.0660	445	—57	134	.1143	—121	—.1623	+ .916	.9517
	9	.0571	.0546	561	—57	135	.1145	— 42	—.1623	+ .916	.9598
	10	.0923	.0755	352	—58	134	.1214	— 39	—.1649	+ .942	.9647
	11	.0848	.0872	330	—58	134	.1213	— 68	—.1658	+ .950	.9609
	12	.0814	.0812	376	—58	136	.1214	— 57	—.1658	+ .950	.9621
	13	.0632	.0488	444	—58	134	.1027	— 12	—.1658	+0.950	.9479
	15	.1924	.1991	300	+58	132	.2394	—100	—.2626	—1.005	.9539
	16	.1892	.1790	322	+56	132	.2298	— 64	—.2682	—1.000	.9424
	17	.2069	.2078	323	+56	132	.2531	— 68	—.2682	—1.000	.9653
	18	.1939	.1912	328	+55	132	.2388	— 51	—.2687	—0.998	.9522
	19	.2206	.1926	319	+55	136	.2523	— 31	—.2687	— .998	.9677
	20	.2064	.2074	304	+55	132	.2506	—118	—.2687	— .998	.9573
						Mean					94.9615
7	2	.0818	.1088	341	—48	125	.1337	+185	+.2097	+0.923	81.3738
	13	.4722	.4627	244	—50	126	.4960	— 11	—.1655	+ .969	.3418
(23)						Mean					81.3578
8	2	.0438	.0356	213	—36	100	.0660	+139	+.0676	+0.650	61.1558
	3	.0383	.0341	228	—36	100	.0640	+102	+.0676	+ .650	.1501
(17)	11	.1636	.1495	196	—37	100	.1811	— 44	—.0538	+ .541	.1298
	12	.1595	.1823	209	—37	100	.1967	— 37	—.0538	+ .541	.1461
	13	.1678	.1622	214	—37	100	.1913	— 8	—.0538	+ .541	.1436
	15	.1983	.2245	237	+37	96	.2471	— 64	—.0854	— .426	.1498
						Mean					61.1459
9	2	.4752	.4860	416	—68	115	.5178	+260	+.1873	+0.631	114.7392
	3	.5146	.4676	458	—68	122	.5331	+191	+.1873	+ .631	.7476
(29)	11	.8372	.8280	371	—70	120	.8654	— 82	—.1478	+ .740	.7189
	13	.8130	.8001	449	—70	120	.8473	— 15	—.1478	+ .740	.7075
	15	.9240	.9426	327	+70	121	.9758	—120	—.2343	— .849	.7186
	18	.9489	.9477	328	+67	120	.9905	— 62	—.2398	— .912	.7328
						Mean					114.7274
10	10	.0253	.0063	300	—60	132	.0469	— 40	+.0296	+0.097	99.0737
	12	.0295	.9887	298	—60	132	.0400	— 49	+.0298	+ .069	.0648
(78)	15	.9722	.9822	337	+60	128	.0236	—104	+.0470	+ .077	.0612
	18	.9556	.9712	460	+58	132	.0223	— 53	+.0480	+ .233	.0680
	19	.9687	.9714	404	+58	132	.0233	— 32	+.0480	+ .233	.0711
	20	.9906	.9534	352	+58	132	.0201	—123	+.0480	+ .233	.0588
						Mean					99.0663

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	′ ″	′ ″		° ′ ″
1	319 59 30	59 52	12 2	+11	11 54	+ 0 14	+ 34	230 12 33
2	57 56	57 56	13 28	+ 9	11 33	+ 0 14	+ 31	12 58
3	58 5	58 24	13 34	+13	12 1	+ 0 14	+ 31	12 32
4	59 48	0 13	12 39	+12	12 52	+ 0 1	+ 13	12 23
5	320 0 48	1 28	11 38	+11	12 57	+ 0 1	— 4	12 49
6	0 18	0 34	11 38	+20	12 24	+ 0 1	— 4	12 41
7	319 55 52	56 2	12 52	+13	9 2	+ 0 0	— 6	12 21
8	59 28	59 12	13 3	+12	12 35	— 0 11	+ 28	12 22
9	57 45	58 38	14 30	+18	12 59	— 0 11	+ 28	12 28
10	59 27	0 13	13 7	+ 6	13 3	— 0 11	+ 23	12 39
11	58 34	59 12	14 13	+ 4	13 10	— 0 11	+ 21	12 36
12	56 38	56 58	15 35	+ 8	12 31	— 0 11	+ 21	12 39
13	58 15	59 5	13 8	+13	12 1	— 0 11	+ 21	12 22
15	320 00 40	1 35	12 13	+10	13 31	— 0 18	— 10	12 50
16	1 28	2 12	10 58	+ 27	13 15	— 0 18	+ 1	12 28
17	2 50	3 45	11 10	+ 20	14 48	— 0 18	+ 1	12 25
18	1 5	1 57	11 3	+25	12 59	— 0 18	+ 2	11 52
19	1 22	1 57	11 22	+18	13 19	— 0 18	+ 2	13 1
20	319 59 30	59 55	12 38	+12	12 32	— 0 18	+ 2	12 29
				Mean				230 12 33.1
2	325 1 15	1 43	13 28	+ 6	15 3	— 0 31	+ 29	235 15 42
13	0 15	0 59	13 8	— 3	13 42	+ 0 24	+ 16	14 36
				Mean				235 15 9.0
2	32 40 22	41 24	13 28	—13	54 7	—11 8	— 89	302 43 27
3	40 16	40 45	13 34	—19	53 46	—11 8	— 89	42 12
11	20 2	21 20	14 13	— 6	34 48	+ 8 46	—100	42 27
12	18 40	18 37	15 35	—11	34 2	+ 8 46	—100	42 23
13	21 10	21 48	13 8	—17	34 20	+ 8 46	—100	42 54
15	16 8	15 24	12 13	— 5	27 54	+13 53	+101	42 4
				Mean				302 42 34.5
2	294 17 35	18 20	13 28	+14	31 40	+ 2 55	+ 48	204 35 52
3	17 33	18 48	13 34	+ 20	32 4	+ 2 55	+ 48	35 22
11	23 23	24 5	14 13	+ 6	38 3	— 2 18	+ 41	35 29
13	22 47	23 22	13 8	+ 19	36 31	— 2 18	+ 41	34 52
15	26 32	28 41	12 13	+ 2	39 51	— 3 38	— 35	35 41
18	27 52	28 53	11 3	+ 2	39 27	— 3 43	— 26	34 45
				Mean				204 35 20.2
10	61 42 56	44 10	13 7	— 3	56 37	+ 5 35	— 73	332 1 25
12	40 24	41 48	15 35	— 4	56 37	+ 5 37	— 73	1 59
15	40 38	40 37	12 13	—11	52 40	+ 8 54	+ 75	1 42
18	41 12	42 16	11 3	—30	52 17	+ 9 6	+ 72	0 59
19	39 25	41 23	11 22	—21	51 25	+ 9 6	+ 72	0 56
20	39 43	40 13	12 38	—13	52 23	+ 9 6	+ 72	2 9
				Mean				332 1 31.7

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean. s	Scale Variation.	Proper Motion.	Parallax *Co-efficient.*	Final Corrected Distance. σ
		East	West.	Refrac.	Aberr.	Scale.					
11	11	.1390	.1408	223	—45	124	.1675	— 53	+.0261	+0.090	74.1895
	12	.1531	.1270	225	—45	124	.1679	— 44	+.0261	+ .090	.1908
(77)	15	.1319	.1356	255	+45	123	.1736	— 78	+.0412	+ .056	.2077
						Mean					74.1960
12	11	.6700	.6604	166	—33	99	.6874	— 38	—.0056	+0.276	53 6815
	13	.6836	.6730	172	—33	99	.7011	— 7	—.0056	+ .276	.6983
(15)	15	.6732	.6743	195	+33	96	.7053	— 56	—.0090	— .138	.6889
						Mean					53.6896
13	1	.3524	.3614	285	—57	136	.3874	+192	—.0720	+0.092	98.3358
	2	.3630	.3550	293	—58	136	.3901	+224	—.0715	+ .050	.3416
(14)	3	.3642	.3513	295	—58	138	.3894	+164	—.0715	+ .050	.3349
	4	.2984	.2968	297	—60	136	.3289	— 3	—.0053	— .191	.3208
	5	.3068	.2918	293	—57	136	.3305	+ 43	—.0026	— .394	.3271
	6	.2970	.2951	299	—57	136	.3278	+ 88	—.0026	— .394	.3289
	7	.3014	.3063	298	—56	136	.3356	+ 91	—.0023	— .419	.3370
	10	.2354	.2393	294	—60	136	.2684	— 40	+.0559	— .066	.3195
	11	.2419	.2395	294	—60	136	.2716	— 70	+.0562	— .094	.3196
	12	.2335	.2293	293	—60	136	.2624	— 59	+.0562	— .094	.3115
	13	.2352	.2496	293	—60	136	.2734	— 13	+.0562	— .094	.3271
	15	.1947	.1884	317	+60	136	.2369	—103	+.0889	+ .242	.3186
	16	.1811	.1681	413	+57	136	.2293	— 66	+.0908	+ .378	.3184
	17	.1604	.1670	366	+57	136	.2137	— 70	+.0908	+ .378	.3024
	18	.1569	.1686	407	+57	136	.2169	— 53	+.0910	+ .390	.3076
	19	.1873	.1810	361	+57	136	.2336	— 32	+.0910	+ .390	.3264
	20	.1854	.1686	329	+57	136	.2233	—122	+.0910	+ .390	.3071
						Mean					98.3226
14	2	.5585	.5620	127	—21	106	.5811	+ 79	+.0881	+0.723	34.6864
	3	.5667	.5729	135	—21	105	.5914	+ 58	+.0881	+ .723	.6946
(18)	10	.7285	.7121	119	—21	104	.7402	— 14	—.0698	+ .646	.6773
	11	.7369	.7223	115	—21	105	.7492	— 25	—.0702	+ .625	.6845
	12	.7356	.7166	123	—21	105	.7465	— 21	—.0702	+ .625	.6822
	13	.7191	.6993	135	—21	104	.7307	— 4	—.0702	+ .625	.6681
	15	.7756	.7645	136	+21	102	.7956	— 36	—.1115	— .521	.6738
	16	.7510	.7642	208	+20	106	.7907	— 23	—.1140	— .384	.6695
	18	.7750	.7772	203	+20	108	.8089	— 19	—.1142	— .370	.6880
	19	.7717	.7725	169	+20	105	.8012	— 11	—.1142	— .370	.6811
	20	.7780	.7722	143	+20	108	.8019	— 43	—.1142	— .370	.6786
						Mean					34.6804
15	2	.9422	.9548	201	—31	106	.9753	+118	+.2018	+0.760	52.1987
	3	.9428	.9546	227	—31	110	.9784	+ 87	+.2018	+ .760	.1987
(22)	10	.3307	.3272	183	—32	106	.3537	— 21	—.1584	+ .835	.2039
	11	.3287	.3188	175	—32	106	.3478	— 37	—.1593	+ .850	.1957
	12	.3230	.3271	194	—32	106	.3510	— 31	—.1593	+ .850	.1995
	13	.3143	.3105	223	—32	110	.3416	— 7	—.1593	+ .850	.1925
	15	.4327	.4583	194	+32	94	.4766	— 55	—.2523	— .938	.2068
	18	.4623	.4506	163	+31	101	.4851	— 28	—.2583	— .972	.2115
						Mean					52.2009

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate	Observed Position Angle.		Zero Correction plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle. π
	East.	West.						
	° ′ ″	′ ″	′ ″	″	′ ″	′ ″		° ′ ″
11	60 27 37	27 48	14 13	— 3	41 52	+ 7 33	— 97	330 48 19
12	25 25	25 33	15 35	— 5	40 59	+ 7 33	— 97	48 8
15	23 52	23 32	12 13	—11	35 44	+11 57	+101	47 58
				Mean				330 48 8.3
11	49 29 30	30 22	14 13	— 4	44 5	+10 34	—130	319 53 21
13	30 2	30 36	13 8	—13	43 14	+10 34	—130	53 25
15	23 57	24 5	12 13	—10	36 4	+16 44	+137	53 18
				Mean				319 53 21.3
1	71 19 56	19 39	12 2	0	31 50	— 6 54	— 73	341 24 43
2	16 25	17 22	13 28	0	30 21	— 6 51	— 73	24 4
3	17 55	18 45	13 34	+ 1	31 55	— 6 51	— 73	24 44
4	13 42	14 30	12 39	+ 1	26 46	— 0 31	— 72	25 14
5	13 6	14 22	11 38	+ 1	25 23	— 0 15	— 66	24 36
6	12 30	13 43	11 38	+ 8	24 53	— 0 15	— 66	24 31
7	8 41	9 25	12 52	+ 3	21 58	— 0 13	— 65	24 43
10	7 2	7 11	13 7	— 1	20 12	+ 5 23	— 74	24 47
11	5 35	6 38	14 13	— 1	20 19	+ 5 25	— 74	24 46
12	3 48	3 50	15 35	— 1	19 23	+ 5 25	— 74	24 32
13	5 57	6 16	13 8	+ 1	19 15	+ 5 25	— 74	24 37
15	3 10	4 4	12 13	—11	15 39	+ 8 34	+ 74	24 21
16	4 43	6 21	10 58	—33	15 57	+ 8 45	+ 69	24 38
17	6 8	7 37	11 10	—23	17 39	+ 8 45	+ 69	24 44
18	4 58	5 50	11 3	—30	16 51	+ 8 46	+ 69	25 12
19	3 38	4 32	11 22	—20	15 7	+ 8 46	+ 69	24 17
20	2 5	3 3	12 38	—13	14 59	+ 8 46	+ 69	24 24
				Mean				341 24 38.4
2	26 54 6	55 10	13 28	—14	7 52	—18 53	—140	296 49 9
3	54 0	56 16	13 34	—20	8 22	—18 53	—140	48 45
10	19 37	21 27	13 7	— 8	33 31	+14 45	—158	46 58
11	19 26	19 38	14 13	— 6	33 39	+14 50	—162	47 0
12	17 28	17 46	15 35	—11	33 1	+14 50	—162	47 4
13	20 3	20 21	13 8	—19	33 1	+14 50	—162	47 17
15	12 35	11 37	12 13	— 3	24 16	+23 28	+185	48 32
16	10 30	12 42	10 58	— 3	22 31	+23 58	+196	47 10
18	11 42	11 58	11 3	— 3	22 50	+24 1	+197	47 12
19	10 10	12 35	11 22	— 4	22 40	+24 1	+197	47 51
20	10 2	9 56	12 38	— 3	22 34	+24 1	+197	48 0
				Mean				296 47 43.5
2	305 0 0	1 40	13 28	+13	14 31	+ 3 55	+ 87	215 19 57
3	1 54	2 42	13 34	+19	16 11	+ 3 55	+ 87	20 43
10	10 13	11 25	13 7	+ 8	24 4	— 3 3	+ 74	21 7
11	9 37	9 55	14 13	+ 6	24 5	— 3 4	+ 71	20 56
12	6 58	8 16	15 35	+11	23 23	— 3 4	+ 71	20 56
13	9 44	10 6	13 8	+19	23 22	— 3 5	+ 71	21 7
15	14 53	16 10	12 13	— 9	27 36	— 4 52	— 54	22 6
18	15 43	15 5	11 3	+18	26 45	— 4 59	— 32	20 44
				Mean				215 20 57.0

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean. s	Scale Variation.	Proper Motion.	Parallax *Co-efficient.*	Final Corrected Distance. σ
		East.	West.	Refrac.	Aberr.	Scale.					
16	2	.0451	.0651	131	—18	107	.0769	+ 68	+.1978	+0.976	30.2940
	3	.0509	.0502	151	—18	107	.0743	+ 50	+.1978	+ .976	.2896
(20)	10	.4275	.4128	116	—19	108	.4405	— 12	—.1554	+ .984	.2965
	11	.4162	.4188	108	—19	108	.4369	— 22	—.1563	+ .982	.2910
	13	.4499	.4011	148	—19	108	.4490	— 4	—.1563	+ .982	.3049
	15	.5196	.5287	108	+19	136	.5503	— 32	—.2475	— .984	.2870
	16	.5260	.5298	137	+18	104	.5536	— 21	—.2528	— .926	.2868
	18	.5404	.5371	137	+18	106	.5647	— 16	—.2533	— .920	.2980
						Mean					30.2935
17	2	.4646	.4644	246	—49	135	.4942	+188	—.0712	+0.052	82.4425
	10	.3210	.3434	246	—50	136	.3618	— 34	+.0555	— .064	.4131
(13)	11	.3304	.3316	246	—50	136	.3607	— 59	+.0558	— .092	.4094
	13	.3578	.3466	246	—50	136	.3818	— 11	+.0558	— .092	.4353
	15	.2947	.2895	266	+50	136	.3338	— 86	+.0884	+ .240	.4167
	20	.2928	.2669	276	+48	135	.3223	—102	+.0904	+ .388	.4075
						Mean					82.4207
18	2	.9388	.9421	230	—41	128	.9701	+159	—.0607	+0.103	69.9266
	10	.8614	.8647	210	—43	127	.8903	— 29	+.0472	— .013	.9344
(12)	11	.8696	.8500	209	—43	127	.8870	— 50	+.0475	— 040	.9290
	12	.8637	.8578	209	—43	128	.8881	— 42	+.0475	— .040	.9309
	13	.8604	.8524	209	—43	127	.8836	— 9	+.0475	— .040	.9297
	15	.8128	.8102	230	+42	128	.8491	— 73	+.0752	+ .188	.9197
	18	.8071	.8033	304	+41	128	.8504	— 37	+.0769	+ .339	.9280
	19	.8118	.8030	251	+41	127	.8472	— 23	+.0769	+ .339	.9262
	20	.8181	.8011	237	+41	127	.8480	— 87	+.0769	+ .339	.9206
						Mean					69.9272
19	11	.9849	.9861	397	—79	23	.0064	— 92	—.1211	+0.529	128.8829
	12	.9814	.9767	410	—79	23	.0013	— 77	—.1211	+ .529	.8793
(62)	15	.0476	.0500	366	+78	23	0823	—135	—.1917	— .662	.8686
	19	.0705	.0634	381	+75	23	.1016	— 42	—.1962	— .763	.8914
						Mean					128.8806
20	2	.8045	.8214	223	—44	120	.8403	+168	— 0985	—0.087	73.7575
	3	.8395	.8172	226	—44	120	.8561	+ 123	—.0985	— .087	.7688
(11)	9	.6494	.6636	228	—44	120	.6844	— 33	+.0758	— .136	.7552
	10	.6614	.6699	221	—45	120	.6927	— 30	+.0770	— .203	.7641
	11	.6725	.6640	220	—45	115	.6948	— 53	+.0774	— .230	.7639
	12	.6730	.6656	221	—45	120	.6964	— 44	+.0774	— .230	.7664
	13	.6560	.6576	223	—45	120	.6841	— 10	+.0774	— .230	.7575
	15	.6016	.5942	228	+45	120	.6347	— 77	+.1225	+ .377	.7543
	16	.5856	.5666	282	+43	118	.6179	— 49	+.1251	+ .502	.7445
	18	.5646	.5910	278	+43	118	.6192	— 40	+.1253	+ .514	.7471
	19	.5870	.5912	252	+43	118	.6279	— 24	+.1253	+ .514	.7574
	20	.6028	.5880	233	+43	118	.6323	— 91	+.1253	+ .514	.7551
						Mean					73.7576

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle.		Zero Correction plus precession, etc.	Refrac	Corrected Mean. p	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle π
	East.	West.						
	° ′ ″	′ ″	′ ″	″	′ ″	′ ″		° ′ ″
2	341 7 47	3 50	13 28	0	19 16	— 8 0	+ 13	251 12 21
3	7 48	6 20	13 34	— 2	20 36	— 8 0	+ 13	12 47
10	340 53 52	54 38	13 7	+ 1	7 23	+ 6 12	— 15	13 9
11	51 57	52 45	14 13	+ 1	6 35	+ 6 15	— 22	12 11
13	55 44	55 50	13 8	— 1	8 54	+ 6 15	— 22	15 25
15	49 42	51 33	12 13	+ 11	3 1	+ 9 52	+ 59	12 55
16	51 14	49 54	10 58	+33	2 5	+10 4	+ 92	12 13
18	51 43	51 24	11 3	+30	3 7	+ 10 5	+ 94	12 56
				Mean				251 12 59.6
2	71 15 34	15 8	13 28	0	28 49	— 8 11	— 87	341 21 7
10	2 41	2 43	13 7	— 1	15 48	+ 6 26	— 88	21 21
11	1 3	0 38	14 13	— 1	15 2	+ 6 28	— 88	20 27
13	1 15	2 23	13 8	+ 1	14 58	+ 6 28	— 88	21 18
15	70 58 12	59 25	12 13	—11	10 50	+10 14	+ 88	20 13
20	57 58	57 30	12 38	—13	10 9	+10 29	+ 82	20 22
				Mean				341 20 48.0
2	68 17 43	17 50	13 28	— 1	31 13	— 9 49	—103	338 21 47
10	1 25	3 22	13 7	— 2	15 28	+ 7 43	—103	22 13
11	1 3	0 58	14 13	— 1	15 13	+ 7 46	—104	21 51
12	67 58 2	58 56	15 35	— 3	14 1	+ 7 46	—104	21 21
13	68 0 20	2 15	13 8	— 2	14 23	+ 7 46	—104	21 56
15	67 57 33	57 45	12 13	—11	9 41	+12 18	+ 105	22 18
18	58 53	59 22	11 3	—30	10 31	+ 12 36	+ 98	22 55
19	57 8	58 34	11 22	—20	8 53	+ 12 36	+ 98	22 3
20	56 12	57 7	12 38	—13	9 4	+ 12 36	+ 98	22 29
				Mean				338 22 5.9
11	278 5 48	7 0	14 13	+ 4	20 41	— 3 4	+ 48	188 17 23
12	4 0	4 20	15 35	+ 9	19 54	— 3 4	+ 48	17 18
15	10 45	11 25	12 13	— 4	23 14	— 4 52	— 44	17 47
19	11 47	11 52	11 22	— 9	23 2	— 4 58	— 36	17 50
				Mean				188 17 34.5
2	79 23 48	24 47	13 28	+ 4	37 50	— 8 35	— 98	349 29 40
3	23 40	25 59	13 34	+ 7	38 31	— 8 35	— 98	29 27
9	8 30	9 58	14 30	+15	23 59	+ 6 39	— 97	29 33
10	10 40	10 56	13 7	+ 2	23 57	+ 6 45	— 96	29 46
11	10 7	10 20	14 13	+ 1	24 28	+ 6 48	— 95	30 11
12	6 45	7 52	15 35	+ 3	22 56	+ 6 48	— 95	29 21
13	10 12	11 0	13 8	+ 7	23 51	+ 6 48	— 95	30 29
15	6 4	7 24	12 13	—10	18 47	+ 10 46	+ 94	29 48
16	8 53	9 40	10 58	—31	19 43	+11 0	+ 86	30 45
18	8 12	8 35	11 3	—28	19 48	+ 11 1	+ 86	30 30
19	6 40	7 37	11 22	—19	18 11	+11 1	+ 86	29 42
20	5 42	7 2	12 38	—11	18 49	+11 1	+ 86	30 35
				Mean				349 29 58.9

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Parallax *Co-efficient.*	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	s				σ
21	2	.0277	.0658	82	—13	100	.0636	+ 50	+.1945	+0.692	22.2720
	10	.4069	.4061	77	—14	100	.4227	— 9	—.1529	+ .775	.2789
(21)	11	.4056	.3932	73	—14	100	.4152	— 16	—.1537	+ .792	.2701
	12	.3958	.3944	80	—14	100	.4116	— 13	—.1537	+ .792	.2668
	13	.3989	.3947	91	—14	100	.4144	— 3	—.1537	+ .792	.2706
	15	.5047	.5059	64	+14	101	.5231	— 24	—.2436	— .892	.2656
	20	.5184	.5169	65	+13	102	.5355	— 28	—.2492	— .943	.2714
						Mean					22.2708
22	2	.7426	.7498	340	—66	123	.7777	+252	—.1171	—0.187	110 6834
	3	.7438	.7714	350	—66	123	.7901	+185	—.1171	— .187	.6891
(9)	13	.5671	.5651	345	—68	128	.5983	— 14	+.0922	— .327	.6849
	15	.4800	.4844	331	+67	128	.5266	—116	+.1461	+ .472	.6672
	16	.4590	.4456	386	+64	128	.5018	— 74	+.1492	+ .590	.6512
	19	.4759	.4712	358	+64	128	.5204	— 36	+.1495	+ .599	.6740
	20	.4736	.4740	340	+65	132	.5193	—137	+.1495	+ .599	.6628
						Mean					110.6732
23	1	.3538	.3482	271	—52	134	.3820	+174	—.1201	—0.156	89.2773
	2	.3584	.3390	276	—53	134	.3801	+203	—.1192	— .199	.2786
(10)	3	.3613	.3465	284	—53	134	.3860	+149	—.1192	— .199	.2791
	4	.2602	.2464	280	—55	135	.2849	— 2	—.0089	— .430	.2703
	5	.2526	.2460	277	—51	135	.2810	+ 39	—.0043	— .604	.2728
	6	.2462	.2428	309	—51	134	.2793	+ 80	—.0043	— .604	.2752
	7	.2490	.2478	290	—51	135	.2814	+ 83	—.0038	— .623	.2779
	8	.1524	.1357	432	—54	135	.1910	—113	+.0919	— .248	.2684
	9	.1444	.1497	293	—54	135	.1801	— 39	+.0919	— .248	.2649
	10	.1484	.1524	270	—54	135	.1812	— 36	+.0933	— .314	.2669
	11	.1523	.1553	268	—55	135	.1843	— 64	+.0938	— .339	.2673
	12	.1550	.1485	272	—55	135	.1826	— 53	+.0938	— .339	.2667
	13	.1528	.1490	278	—55	135	.1824	— 12	+.0938	— .339	.2706
	15	.0830	.0692	267	+54	135	.1173	— 93	+.1485	+ .484	.2627
	16	.0650	.0636	310	+52	135	.1096	— 60	+.1517	+ .600	.2630
	17	.0568	.0660	284	+52	135	.1042	— 64	+.1517	+ .600	.2572
	18	.0544	.0614	307	+52	135	.1030	— 48	+.1520	+ .609	.2580
	19	.0596	.0628	288	+52	135	.1044	— 29	+.1520	+ .609	.2613
	20	.0694	.0656	274	+52	135	.1093	—111	+.1520	+ .609	.2580
						Mean					89.2683
24	11	.4972	.4884	25	— 5	29	.4977	— 6	+.0292	+0.064	8.5271
	13	.4776	.4791	26	— 5	32	.4837	— 1	+.0292	+ .064	.5136
(75)						Mean					8.5204
25											
26											

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle.		Zero Correction plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle *π*
	East.	West.						
	° ′ ″	′ ″	′ ″	″	′ ″	′ ″		° ′ ″
2	298 44 53	50 40	13 28	+14	1 28	+12 23	+229	209 16 13
10	299 12 10	13 43	13 7	+ 8	26 11	— 9 34	+202	17 29
11	11 45	10 38	14 13	+ 6	25 30	— 9 38	+195	16 31
12	8 36	5 25	15 35	+11	22 47	— 9 38	+195	14 30
13	10 50	9 6	13 8	+19	23 25	— 9 38	+195	15 21
15	21 38	21 3	12 13	+ 4	33 38	—15 11	—158	17 11
20	20 40	20 32	12 38	+ 5	33 19	—15 32	—108	17 22
				Mean				209 16 22.4
2	85 15 2	16 8	13 28	+ 6	29 9	— 5 22	— 64	355 24 24
3	16 17	17 35	13 34	+11	30 41	— 5 22	— 64	25 2
13	7 0	7 5	13 8	+10	20 20	+ 4 14	— 62	24 36
15	5 40	5 50	12 13	— 8	17 50	+ 6 43	+ 59	24 35
16	6 55	8 10	10 58	—28	18 2	+ 6 52	+ 53	24 44
19	5 53	6 13	11 22	—16	17 9	+ 6 52	+ 53	24 19
20	5 15	5 17	12 38	— 9	17 45	+ 6 52	+ 53	25 10
				Mean				355 24 41.4
1	85 58 25	59 45	12 2	+ 8	11 15	— 6 39	— 79	356 4 21
2	56 44	57 45	13 28	+ 6	10 48	— 6 36	— 79	4 44
3	57 6	58 2	13 34	+11	11 19	— 6 36	— 79	4 21
4	53 18	53 55	12 39	+ 9	6 25	— 0 30	— 73	4 54
5	52 30	53 10	11 38	+ 8	4 36	— 0 14	— 62	3 52
6	51 37	53 26	11 38	+27	4 37	— 0 14	— 62	4 18
7	48 48	48 42	12 52	+15	1 52	— 0 6	— 60	4 45
8	46 12	47 43	13 3	— 5	59 56	+ 5 6	— 78	4 22
9	45 25	45 34	14 30	+21	0 21	+ 5 6	— 78	4 29
10	46 30	47 30	13 7	+ 3	0 10	+ 5 11	— 77	4 32
11	45 10	46 20	14 13	+ 2	0 0	+ 5 13	— 76	4 15
12	43 18	44 27	15 35	+ 6	59 34	+ 5 13	— 76	4 31
13	45 52	46 40	13 8	+10	59 34	+ 5 13	— 76	4 44
15	43 43	44 12	12 13	— 8	56 3	+ 8 17	+ 73	4 27
16	45 27	46 0	10 58	—27	56 15	+ 8 27	+ 66	4 37
17	45 43	47 46	11 10	—18	57 37	+ 8 27	+ 66	4 23
18	45 18	45 28	11 3	—25	56 46	+ 8 28	+ 65	4 47
19	44 5	44 6	11 22	—15	55 13	+ 8 28	+ 65	4 3
20	43 15	43 37	12 38	— 9	55 57	+ 8 28	+ 65	5 2
				Mean				356 4 29.8
11	61 51 28	55 42	14 13	— 3	7 46	+ 6 2	—852	333 8 11
13	62 5 29	1 51	13 8	— 5	16 43	+ 6 3	—852	18 4
				Mean				333 13 7.5

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Parallax *Coefficient.*	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	*s*				*σ*
27	2	.2265	.2096	118	—23	109	.2380	+ 87	+.1228	+0.222	38.3724
	3	.2274	.1914	122	—23	109	.2298	+ 64	+.1228	+ .222	.3619
(30)	10	.4421	.4243	141	—23	108	.4554	— 16	—.0969	+ .335	.3612
	11	.4299	.4405	116	—23	108	.4549	— 27	—.0974	+ .361	.3594
	12	.4387	.4402	118	—23	108	.4593	— 23	—.0974	+ .361	.3642
	13	.4381	.4337	121	—23	108	.4561	— 5	—.0974	+ .361	.3628
	15	.4898	.4942	114	+23	108	.5161	— 40	—.1546	— .504	.3510
	16	.4972	.5186	129	+22	108	.5334	— 26	—.1579	— .618	.3650
	18	.5107	.4993	130	+22	108	.5306	— 21	—.1582	— .627	.3622
	20	.4933	.5113	117	+22	108	.5266	— 48	—.1582	— .627	.3555
						Mean					38.3616
28	11	.8154	.8118	338	—68	112	.8433	— 80	—.1002	+0.381	111.7400
	12	.8212	.8102	343	—68	112	.8459	— 67	—.1002	+ .381	.7439
(60)	13	.8050	.8032	351	—68	112	.8351	— 14	—.1002	+ .381	.7384
	15	.8830	.8616	329	+68	112	.9147	—117	—.1588	— .523	.7375
	18	.8925	.8660	374	+65	112	.9258	— 60	—.1625	— .645	.7490
	19	.8712	.8688	353	+65	112	.9145	— 36	—.1625	— .645	.7401
						Mean					111.7415
29	3	.1795	.1523	129	—21	112	.1876	+ 60	—.1601	—0.440	36.0279
	11	.8741	.8697	111	—22	112	.8917	— 26	+.1259	+ .567	.0077
(5)	13	.8725	.8763	125	—22	112	.8956	— 5	+.1259	+ .567	.0137
						Mean					36 0164
30 (69)	11	.2444	.2182	60	—11	78	.2440	— 13	+.1536	—0.793	18.3861
31 (64)	11	.9278	.9310	179	—37	102	.9525	— 43	—.0820	+0.258	59.8695
32	1	.8124	.7994	227	—45	130	.8343	+150	+.1095	+0.100	76.9601
	2	.8056	.7947	235	—46	130	.8293	+175	+.1087	+ .142	.9573
(31)	3	.7998	.8035	238	—46	130	.8311	+128	+.1087	+ .142	.9544
	4	.9032	.9052	238	—47	124	.9329	— 2	+.0081	+ .378	.9457
	5	.9166	.9137	235	—44	124	.9439	+ 34	+.0039	+ .560	.9584
	6	.9144	.8940	256	—44	130	.9356	+ 69	+.0039	+ .560	.9536
	7	.9134	.9000	245	—44	124	.9364	+ 71	+.0035	+ .580	.9544
	8	.0047	.0115	235	—46	124	.0366	— 98	—.0842	+ .191	.9451
	9	.0119	.0014	246	—46	124	.0363	— 34	—.0842	+ .191	.9512
	10	.0117	.9983	232	—47	124	.0331	— 31	—.0856	+ .258	.9477
	11	.0044	.0053	231	—47	124	.0328	— 55	—.0860	+ .284	.9449
	12	.0090	.0010	233	—47	124	.0332	— 46	—.0860	+ .284	.9462
	13	.9911	.0017	236	—47	124	.0249	— 10	—.0860	+ .284	.9415
	15	.0522	.0566	235	+47	124	.0922	— 81	—.1365	— .430	.9421
	16	.0533	.0692	270	+45	125	.1025	— 52	—.1394	— .552	.9508
	17	.0687	.0591	253	+45	124	.1033	— 55	—.1394	— .552	.9513
	18	.0672	.0500	276	+45	124	.1003	— 41	—.1396	— .562	.9494
	19	.0698	.0420	254	+45	124	.0954	— 25	—.1396	— .562	.9461
	20	.0621	.0665	240	+45	121	.1025	— 96	—.1396	— .562	.9461
						Mean					76.9498

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued*).

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc	Refrac.	Corrected Mean. *p*	Proper Motion	Parallax *Coefficient.*	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	′ ″	′ ″		° ′ ″
2	266 44 0	44 25	13 28	+ 7	57 48	+15 21	+183	177 15 15
3	45 17	44 12	13 34	+12	58 30	+15 21	+183	15 3
10	267 14 38	13 58	13 7	— 6	27 19	—11 59	+178	16 3
11	12 58	13 44	14 13	+ 2	27 37	—12 3	+176	16 6
12	11 6	9 35	15 35	+ 6	26 2	—12 3	+176	15 13
13	11 3	11 43	13 8	+12	24 43	—12 3	+176	14 7
15	22 30	24 28	12 13	— 8	35 34	—19 4	—169	15 10
16	25 5	26 10	10 58	—27	36 8	—19 28	—151	15 17
18	26 52	25 48	11 3	—23	37 40	—19 30	—149	16 26
20	22 0	24 2	12 38	— 9	35 30	—19 30	—149	15 20
				Mean				177 15 24.0
11	268 23 45	24 35	14 13	+ 2	38 25	— 4 7	+ 60	178 34 9
12	21 18	22 28	15 35	+ 6	37 34	— 4 7	+ 60	34 0
13	23 40	24 24	13 8	+ 12	37 22	— 4 7	+ 60	34 1
15	28 42	29 56	12 13	— 7	41 25	— 6 31	— 57	34 13
18	30 20	30 52	11 3	—25	41 14	— 6 40	— 51	33 26
19	30 22	30 00	11 22	—15	41 18	— 6 40	— 51	34 19
				Mean				178 34 1.3
3	101 6 44	4 42	13 34	+18	19 35	—12 54	—178	11 5 43
11	100 40 27	38 44	14 13	+ 5	53 53	+10 15	—165	2 38
13	42 10	42 40	13 8	+17	55 50	+10 15	—165	5 30
				Mean				11 4 37.0
11	119 16 43	11 55	14 13	+ 6	28 38	+11 41	—234	29 38 16
11	260 49 18	50 32	14 13	+ 2	4 10	— 8 19	+117	170 56 2.0
1	268 18 42	19 55	12 2	+ 6	31 26	+ 8 10	+ 93	172 40 22
2	16 50	17 32	13 28	+ 6	30 45	+ 8 6	+ 93	40 24
3	17 37	18 22	13 34	+ 9	31 43	+ 8 6	+ 93	40 28
4	26 12	26 36	12 39	+ 8	39 11	+ 0 36	+ 87	39 43
5	27 43	27 50	11 38	+ 6	39 31	+ 0 18	+ 75	40 8
6	26 38	27 51	11 38	+23	39 16	+ 0 18	+ 75	40 18
7	22 58	23 47	12 52	+12	36 26	+ 0 15	+ 73	40 28
8	33 25	33 30	13 3	+ 8	46 38	— 6 15	+ 92	40 44
9	31 55	32 2	14 30	+ 18	46 46	— 6 15	+ 92	40 34
10	33 5	33 55	13 7	+ 3	46 40	— 6 20	+ 91	40 32
11	32 24	33 5	14 13	+ 2	46 59	— 6 23	+ 90	40 37
12	30 31	31 8	15 35	+ 5	46 30	— 6 23	+ 90	40 50
13	32 30	33 5	13 8	+ 8	46 3	— 6 23	+ 90	40 36
15	38 40	40 8	12 13	— 8	51 31	—10 6	— 88	40 34
16	40 45	41 30	10 58	—30	51 35	—10 19	— 80	40 18
17	42 13	43 27	11 10	—19	53 41	—10 19	— 80	40 48
18	262 40 53	41 27	11 3	—27	52 46	—10 20	— 79	41 8
19	40 12	40 58	11 22	—17	51 40	—10 20	— 79	40 51
20	37 53	38 32	12 38	—10	50 40	—10 20	— 79	40 6
				Mean				172 40 30.0

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Parallax Co-*efficient.*	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	*s*				*σ*
33	2	.9723	.9735	124	—21	115	.9944	+ 80	—.1815	—0.587	34.8134
	3	.9855	.9747	137	—21	115	.0029	+ 58	—.1815	— .587	.8197
(4)	11	.6619	.6613	111	—21	115	.6818	— 25	+.1430	— .701	.8133
	12	.6594	.6642	118	—21	115	.6827	— 21	+.1430	— .701	.8146
	13	.6615	.6579	131	—21	115	.6819	— 4	+.1430	— .701	.8155
	15	.5516	.5545	98	+21	113	.5759	— 36	+.2264	+ .815	.8092
	18	.5535	.5761	99	+20	116	.5880	— 19	+.2317	+ .887	.8292
						Mean					34.8164
34	2	.4744	.4310	106	—20	116	.4726	+ 78	+.0184	—0.296	34.4950
	11	.4828	.5022	105	—21	113	.5119	— 25	—.0154	— .158	.4920
(37)	13	.5002	.4982	106	—21	113	.5187	— 4	—.0154	— .158	.5009
						Mean					34.4960
35	11	.5791	.5869	73	—14	105	.5993	— 16	+.0507	—0.529	22.6416
	13	.5724	.5822	79	—14	101	.5938	— 3	+.0507	— .529	.6374
(66)						Mean					22.6395
36	2	.5805	.5901	97	—13	102	.6039	+ 51	—.1805	—0.967	22.4161
	3	.5566	.5800	111	—13	104	.5884	+ 38	—.1805	— .967	.3993
(1)	10	.2344	.2589	84	—14	102	.2637	— 9	+.1412	— .952	.3918
	11	.2540	.2531	79	—14	102	.2702	— 16	+.1420	— .945	.3985
	12	.2634	.2490	91	—14	102	.2741	— 13	+.1420	— .945	.4027
	13	.2619	.2501	106	—14	102	.2553	— 3	+.1420	— .945	.4049
	15	.1350	.1192	63	+13	98	.1444	— 23	+.2249	+ .918	.3788
	18	.1366	.1154	112	+13	102	.1487	— 12	+.2301	+ .826	.3882
						Mean					22.3977
37	2	.6800	.6808	146	—28	114	.7029	+109	+.0296	—0.246	46.7402
	3	.6756	.6848	145	—28	114	.7026	+ 79	+.0296	— .246	.7369
(35)	4	.7040	.6981	146	—29	114	.7234	— 1	+.0022	— .007	.7254
	5	.7052	.7086	145	—27	114	.7294	+ 21	+.0011	+ .210	.7353
	6	.7098	.6964	144	—27	118	.7259	+ 43	+.0011	+ .210	.7340
	7	.7106	.6976	146	—27	114	.7267	+ 44	+.0010	+ .236	.7351
	8	.7296	.7294	141	—29	114	.7514	— 61	—.0236	— .200	.7191
	9	.7345	.7399	142	—29	114	.7592	— 21	—.0236	— .200	.7309
	10	.7349	.7305	145	—29	114	.7550	— 20	—.0239	— .133	.7274
	11	.7333	.7332	145	—29	114	.7556	— 34	—.0241	— .106	.7267
	12	.7322	.7305	145	—29	114	.7537	— 29	—.0241	— .106	.7253
	13	.7242	.7366	145	—29	114	.7527	— 6	—.0241	— .106	.7266
	15	.7390	.7317	164	+29	118	.7658	— 50	—.0383	— .039	.7220
	16	.7152	.7370	232	+28	117	.7631	— 32	—.0391	— .184	.7184
	17	.7358	.7275	197	+28	114	.7648	— 34	—.0391	— .184	.7199
	18	.7323	.7253	232	+28	114	.7655	— 26	—.0392	— .196	.7212
	19	.7366	.7198	195	+28	114	.7612	— 16	—.0392	— .196	.7179
	20	.7277	.7378	172	+28	116	.7637	— 59	—.0392	— .196	.7161
						Mean					47.7266

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Corrections plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″		′ ″	′ ″		° ′ ″
2	111 10 24	10 52	13 28	+14	24 20	—10 22	—165	21 13 59
3	10 48	11 30	13 34	+20	25 3	—10 22	—165	13 48
11	110 54 46	55 46	14 13	+ 6	9 35	+ 8 15	—147	16 26
12	51 35	51 35	15 35	+11	7 21	+ 8 15	—147	14 54
13	53 10	55 24	13 8	+ 19	7 46	+ 8 15	—147	15 32
15	49 17	48 43	12 13	+ 1	1 14	+13 6	+ 126	14 46
18	52 48	52 7	11 3	— 2	3 29	+13 25	+ 97	16 39
				Mean				21 15 9.1
2	236 3 27	3 30	13 28	— 7	16 49	+ 20 56	+199	146 39 57
11	41 28	40 4	14 13	— 4	54 55	—16 30	+ 207	39 8
13	40 23	40 53	13 8	— 8	53 38	—16 30	+207	38 46
				Mean				146 39 17.0
11	213 17 2	17 24	14 13	— 6	31 20	—24 2	+269	123 8 24
13	17 25	17 40	13 8	—17	30 23	—24 3	+269	8 21
				Mean				123 8 22.5
2	171 48 14	47 43	13 28	— 5	1 22	+16 30	+ 44	82 19 8
3	45 48	51 2	13 34	— 9	1 50	+16 30	+ 44	18 42
10	172 18 12	19 36	13 7	— 3	31 58	—13 8	+ 83	18 59
11	18 17	20 29	14 13	— 2	33 34	—13 13	+ 91	20 23
12	18 48	16 43	15 35	— 4	33 17	—13 13	+ 91	20 48
13	19 20	18 40	13 8	— 8	32 0	—13 13	+ 91	19 44
15	29 8	29 8	12 13	+ 2	41 23	—21 1	—139	19 13
18	29 55	31 11	11 3	+27	42 3	—21 30	—183	18 37
				Mean				82 19 26.8
2	239 6 5	6 55	13 28	— 5	19 53	+15 3	+146	149 36 49
3	7 28	8 15	13 34	— 7	21 19	+15 3	+146	37 21
4	22 14	22 52	12 39	— 7	35 4	+ 1 8	+152	36 32
5	24 14	24 12	11 38	— 6	35 45	+ 0 33	+145	37 2
6	24 0	25 7	11 38	— 7	36 5	+ 0 33	+145	37 47
7	19 22	20 25	12 52	— 8	32 38	+ 0 29	+143	37 19
8	35 38	35 52	13 3	— 6	48 42	—11 37	+148	37 46
9	34 12	34 12	14 30	— 7	48 35	—11 37	+148	37 21
10	35 18	35 28	13 7	— 3	48 28	—11 48	+151	37 13
11	34 18	34 52	14 13	— 3	48 45	—11 52	+151	37 16
12	31 55	32 33	15 35	— 5	47 44	—11 52	+151	36 57
13	34 2	34 35	13 8	— 6	47 20	—11 52	+ 151	36 46
15	44 32	45 45	12 13	—11	57 11	—18 47	—156	37 9
16	46 17	47 26	10 58	—32	57 18	—19 11	—152	36 43
17	48 28	49 4	11 10	—22	59 34	—19 11	—152	37 23
18	46 30	47 0	11 3	—29	57 19	—19 13	—151	36 22
19	46 3	46 18	11 22	—20	57 12	—19 13	—151	37 4
20	44 18	44 55	12 38	—13	57 1	—19 13	—151	37 8
				Mean				149 37 6.6

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Parallax *Co-efficient.*	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	*s*				σ
38	2	.1008	.0942	337	—66	113	.1274	+255	+.0898	+0.043	112.2433
	3	.0889	.1011	340	—66	113	.1252	+187	+.0898	+ .043	.2343
(32)	11	.2728	.2700	336	—68	113	.3009	— 80	—.0711	+ .187	.2242
	12	.2472	.2810	335	—68	113	.2935	— 67	—.0711	+ .187	.2181
	13	.2560	.2598	336	—68	112	.2873	— 14	—.0711	+ .187	.2172
	15	.3051	.3069	345	+68	113	.3500	—118	—.1127	— .335	.2212
	18	.2970	.2850	334	+65	113	.3339	— 60	—.1154	— .475	.2064
	19	.2952	.2910	392	+65	113	.3415	— 37	—.1154	— .475	.2163
	20	.2980	.3130	360	+ 65	113	.3507	—139	—.1154	— .475	.2153
						Mean					112.2206
39	1	.8614	.8446	383	—67	130	.8886	+222	—.1662	—0.433	113.7390
	2	.8448	.8534	383	—68	105	.8822	+259	—.1651	— .473	.7369
(8)	3	.8484	.8438	415	—68	106	.8825	+190	— 1651	— .473	.7303
	6	.7040	.7114	506	—66	105	.7533	+102	—.0060	— .798	.7473
	9	.5794	.5372	466	—69	103	.5994	— 50	+.1274	— .517	.7152
	10	.5686	.5601	362	—69	107	.5955	— 46	+.1295	— .575	.7130
	11	.5678	.5612	354	—70	105	.5945	— 81	+.1302	— .598	.7089
	13	.5601	.5579	404	—70	108	.5943	— 15	+.1302	— .598	.7153
	15	.4675	.4617	322	+69	108	.5057	—119	+.2062	+ .724	.7093
	16	.4474	.4601	324	+66	108	.4946	— 76	+.2106	+ .809	.7080
	17	.4422	.4408	317	+66	108	.4818	— 81	+.2106	+ .809	.6947
	18	.4532	.4473	331	+66	108	.4919	— 61	+.2110	+ .816	.7073
	19	.4398	.4573	326	+66	108	.4897	— 37	+.2110	+ .816	.7075
	20	.4372	.4402	324	+66	108	.4797	—141	+.2110	+ .816	.6871
						Mean					113.7157
40	2	.1750	.1744	288	—57	138	.2061	+219	+.0763	—0.025	96.3040
	3	.1687	.1808	290	—57	138	.2063	+160	+.0763	— .025	.2983
(33)	11	.3050	.3063	287	—59	138	.3367	— 69	—.0605	+ .119	.2708
	12	.2842	.3048	288	—59	138	.3256	— 58	—.0605	+ .119	.2608
	13	.3034	.3065	289	—59	138	.3361	— 12	—.0605	+ .119	.2759
	15	.3279	.3275	308	+59	138	.3726	—101	—.0959	— .267	.2632
	18	.3268	.3224	393	+56	138	.3777	— 52	—.0982	— .414	.2690
						Mean					96.2774
41	2	.0414	.0432	120	—20	126	.0646	+ 78	—.0685	—0.650	33.9956
(38)	15	.8546	.8660	131	+21	126	.8878	— 35	+.0841	+ .426	.9739
						Mean					33.9848
42	2	.2542	.2492	422	—73	112	.2864	+281	—.1703	—0.508	123.1377
	3	.2624	.2463	457	—73	107	.2920	+205	—.1703	— .508	.1357
(7)	16	.8572	.8356	345	+72	112	.8879	— 82	+.2172	+ .833	.1076
	18	.8465	.8353	356	+72	110	.8833	— 66	+.2176	+ .839	.1051
	19	.8395	.8350	352	+72	112	.8794	— 40	+.2176	+ .839	.1038
						Mean					123.1180

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle. π
2	256° 27′ 28″	28′ 18″	13′ 28″	+ 2″	41′ 24″	+ 5′ 53″	+ 64	166° 48′ 40″
3	28 27	29 48	13 34	+ 6	42 48	+ 5 53	+ 64	49 10
11	39 4	39 28	14 13	+ 1	53 30	— 4 38	+ 63	48 44
12	37 35	37 32	15 35	+ 1	53 10	— 4 38	+ 63	49 6
13	39 10	39 43	13 8	+ 5	52 39	— 4 38	+ 63	48 48
15	44 12	46 52	12 13	—10	57 35	— 7 20	— 62	49 34
18	46 0	47 10	11 3	—29	57 9	— 7 31	— 58	48 27
19	46 42	46 48	11 22	—19	57 48	— 7 31	— 58	49 55
20	44 13	44 55	12 38	—12	57 0	— 7 31	— 58	49 22
				Mean				166 49 5.1
1	103 8 12	9 4	12 2	+ 14	20 54	— 3 54	— 56	13 16 53
2	6 25	7 13	13 28	+12	20 29	— 3 52	— 55	17 17
3	7 12	8 24	13 34	+18	21 40	— 3 52	— 55	17 34
6	4 30	6 2	11 38	+38	17 32	— 0 9	— 35	17 27
9	102 59 56	0 22	14 30	+32	15 11	+ 3 0	— 54	17 22
10	103 1 2	1 55	13 7	+ 7	14 42	+ 3 2	— 52	17 4
11	102 59 52	0 38	14 13	+ 5	14 33	+ 3 4	— 50	16 48
13	103 00 2	0 53	13 8	+18	13 51	+ 3 4	— 50	17 1
15	102 59 47	0 47	12 13	— 2	12 28	+ 4 51	+ 45	17 16
16	103 1 13	2 23	10 58	—12	12 34	+ 4 57	+ 38	17 16
17	2 22	3 13	11 10	— 7	13 50	+ 4 57	+ 38	16 56
18	0 55	1 57	11 3	—10	12 19	+ 4 58	+ 37	16 40
19	102 59 48	1 5	11 22	— 2	11 47	+ 4 58	+ 37	16 57
20	59 16	59 44	12 38	— 3	12 5	+ 4 58	+ 37	17 30
				Mean				13 17 8.6
2	252 27 5	26 16	13 28	0	40 8	+ 7 3	+ 74	162 48 38
3	28 4	28 28	13 34	+ 1	41 51	+ 7 3	+ 74	49 27
11	40 35	41 15	14 13	0	55 8	— 5 34	+ 75	49 30
12	39 43	38 5	15 35	+ 1	55 30	— 5 34	+ 75	50 34
13	40 15	40 53	13 8	+ 2	53 44	— 5 34	+ 75	49 1
15	46 13	47 45	12 13	—11	59 1	— 8 48	— 74	49 27
18	47 52	47 58	11 3	—30	58 28	— 9 1	— 69	48 12
				Mean				162 49 15.6
2	212 1 28	2 24	13 28	—13	15 11	+20 8	+158	122 37 16
15	49 32	51 18	12 13	— 6	2 32	—25 17	—199	35 44
				Mean				122 36 30.0
2	105 25 50	26 42	13 28	+12	39 56	— 3 22	— 50	15 37 16
3	27 17	27 13	13 34	+18	41 7	— 3 22	— 50	37 33
16	21 57	23 13	10 58	—10	33 22	+ 4 19	+ 33	37 24
18	21 7	22 12	11 3	— 9	32 46	+ 4 20	+ 32	36 28
19	21 42	21 17	11 22	— 4	32 47	+ 4 20	+ 32	37 18
				Mean				15 37 11.8

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean. s	Scale Variation.	Proper Motion.	Parallax *Coefficient.*	Final Corrected Distance. σ
		East.	West.	Refrac.	Aberr.	Scale.					
43	1	.1198	.1144	199	—38	108	.1423	+127	+.0087	—0.377	65.1589
	2	.1202	.1164	202	—39	105	.1434	+148	+.0086	— .340	.1624
(34)	3	.1072	.1286	206	—39	105	.1434	+108	+.0086	— .340	.1584
	10	.1334	.1292	201	—40	105	.1562	— 27	—.0072	— .231	.1433
	11	.1330	.1302	199	—40	105	.1563	— 47	—.0072	— .204	.1418
	12	.1372	.1324	201	—40	105	.1597	— 39	—.0072	— .204	.1460
	13	.1285	.1371	204	—40	105	.1580	— 8	—.0072	— .204	.1474
	15	.1291	.1129	231	+40	114	.1578	— 68	—.0116	+ .063	.1402
	16	.1065	.1251	339	+38	110	.1628	— 44	—.0120	— .084	.1453
	18	.1013	.1075	327	+38	108	.1500	— 35	—.0120	— .098	.1332
	19	.1082	.1001	277	+38	105	.1445	— 21	—.0120	— .098	.1291
	20	.1226	.1394	243	+38	108	.1682	— 81	—.0120	— .098	.1468
						Mean					65.1461
44	2	.1214	.1514	187	—34	108	.1614	+130	—.0286	—0.496	57.1394
	3	.0957	.1632	194	—34	108	.1552	+ 95	—.0286	— .496	.1297
(36)	10	.1050	.0813	182	—35	104	.1172	— 23	+.0219	— .396	.1317
	11	.1076	.0924	179	—35	107	.1240	— 41	+.0221	— .372	.1372
	13	.0948	.0884	191	—35	104	.1165	— 7	+.0221	— .372	.1331
	15	.0611	.0733	214	+35	107	.1017	— 60	+.0347	+ .240	.1335
						Mean					57.1341
45	2	.2294	.1670	379	—63	111	.2336	+253	—.1844	—0.609	106.0667
	15	.7967	.7729	300	+64	111	.8250	—111	+.2306	+ .832	.0552
(54)						Mean					106.0610
46 (67)	11	.3643	.3373	157	—27	124	.3757	— 32	+.1385	—0.932	44.4990
47	12	.6216	.5740	391	—80	32	.6184	— 78	—.0516	+0.063	130.5598
	13	.5923	.5929	386	—80	32	.6127	— 17	—.0516	+ .063	.5602
(63)	19	.6220	.6042	478	+76	30	.6579	— 43	—.0838	— .362	.5652
						Mean					130.5617
48	1	.8930	.8908	202	—30	115	.9198	+ 99	—.1233	—0.849	50.7955
	2	.8974	.8948	198	—30	114	.9235	+116	—.1224	— .832	.8020
(44)	3	.8927	.9083	222	—30	114	.9303	+ 85	—.1224	— .832	.8057
	4	.7802	.7702	214	—31	114	.8041	— 1	—.0091	— .686	.7861
	5	.7692	.7614	208	—29	114	.7938	+ 33	—.0044	— .499	.7863
	6	.7539	.7722	265	—29	116	.7975	+ 45	—.0044	— .499	.7912
	7	.7687	.7475	233	—29	110	.7887	+ 47	—.0039	— .472	.7834
	8	.6814	.6796	213	—30	114	.7093	— 64	+.0941	— .809	.7866
	9	.6653	.6743	245	—30	114	.7019	— 22	+.0941	— .809	.7834
	10	.6770	.6815	181	—31	114	.7048	— 21	+.0957	— .771	.7885
	11	.6818	.6780	172	—31	114	.7046	— 36	+.0962	— .755	.7875
	12	.6745	.6767	192	—31	114	.7023	— 30	+.0962	— .755	.7858
	13	.6705	.6747	215	—31	114	.7016	— 7	+.0962	— .755	.7874
	15	.6026	.5930	199	+31	116	.6316	— 53	+.1522	+ .672	.7871
	16	.5727	.5882	298	+30	116	.6241	— 34	+.1555	+ .547	.7832
	17	.5852	.5900	251	+30	116	.6265	— 36	+.1555	+ .547	.7854
	18	.5812	.5751	293	+29	115	.6211	— 27	+.1558	+ .534	.7811
	19	.5778	.5737	246	+29	114	.6138	— 16	+.1558	+ .534	.7749
	20	.5964	.5919	256	+29	116	.6334	— 63	+.1558	+ .534	.7898
						Mean					50.7880

Table VI.—Results of Measures of Angle. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. p	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	′ ″	′ ″		° ′ ″
1	233 26 4	27 20	12 2	— 9	38 35	+11 13	+101	143 50 37
2	23 47	24 40	13 28	— 8	37 34	+11 8	+104	50 19
3	25 44	25 45	13 34	—10	39 8	+11 8	+104	50 59
10	46 0	47 2	13 7	— 5	59 33	— 8 44	+108	51 7
11	45 4	45 52	14 13	— 4	59 37	— 8 47	+109	50 58
12	43 15	43 33	15 35	— 7	58 52	— 8 47	+109	50 55
13	45 53	45 35	13 8	—11	58 41	— 8 48	+109	50 56
15	53 28	55 5	12 13	—11	6 19	—13 55	—114	51 24
16	55 58	55 13	10 58	—29	6 5	—14 13	—113	50 42
18	54 56	55 52	11 3	—27	6 48	—14 15	—112	51 3
19	54 48	56 15	11 22	—19	6 35	—14 15	—112	51 39
20	52 13	52 18	12 38	—12	4 42	—14 15	—112	50 1
				Mean				143 50 53.3
2	223 19 12	16 18	13 28	—11	31 2	+12 35	+108	133 45 16
3	17 30	19 20	13 34	—16	31 43	+12 35	+108	45 3
10	41 55	41 54	13 7	— 7	54 54	— 9 53	+116	45 22
11	38 43	41 17	14 13	— 5	54 8	— 9 56	+117	44 23
13	40 55	40 51	13 8	—16	53 45	— 9 56	+117	44 55
15	50 8	50 40	12 13	— 9	2 28	—15 45	—126	45 39
				Mean				133 45 6 3
2	112 43 4	42 0	13 28	+14	56 14	— 3 12	— 53	22 53 43
15	37 44	37 40	12 13	+ 2	49 57	+ 4 1	+ 40	53 53
				Mean				22 53 48 0
11	174 32 24	32 0	14 13	— 2	46 23	— 7 6	+ 52	84 39 5.0
12	249 19 12	20 30	15 35	— 2	35 24	— 4 12	+ 56	159 31 43
13	22 41	23 17	13 8	— 1	36 6	— 4 12	+ 56	32 38
19	28 15	29 0	11 22	—21	39 38	— 6 48	— 53	32 30
				Mean				159 32 17.0
1	195 28 36	29 55	12 2	—14	41 4	+11 41	+ 68	105 53 22
2	25 48	26 26	13 28	—12	39 24	+11 36	+ 74	52 27
3	27 57	28 55	13 34	—19	41 41	+11 36	+ 74	53 50
4	38 16	39 26	12 39	—16	51 15	+ 0 52	+102	52 9
5	41 17	42 49	11 38	—15	53 26	+ 0 25	+119	54 26
6	40 58	41 57	11 38	—39	52 27	+ 0 25	+119	53 52
7	36 23	26 53	12 52	—25	49 5	+ 0 22	+121	53 32
8	48 38	50 8	13 3	—19	2 7	— 9 0	+ 80	53 24
9	48 10	49 2	14 30	—33	2 33	— 9 0	+ 80	53 32
10	48 54	48 46	13 7	— 8	1 49	— 9 9	+ 89	52 51
11	47 28	49 7	14 13	— 6	2 25	— 9 12	+ 92	53 15
12	45 25	47 0	15 35	—10	1 37	— 9 12	+ 92	53 9
13	47 28	48 43	13 8	—18	0 56	— 9 12	+ 92	52 41
15	55 32	57 4	12 13	+ 1	8 32	—14 35	—110	52 58
16	57 25	59 15	10 58	+ 9	9 27	—14 54	—121	53 20
17	59 30	0 18	11 10	+ 6	11 11	—14 54	—121	53 28
18	57 5	57 12	11 3	+ 7	8 18	—14 56	—122	51 48
19	57 7	57 45	11 22	+ 4	8 52	—14 56	—122	53 11
20	54 57	56 52	12 38	+ 1	8 33	—14 56	—122	53 7
				Mean				105 53 10.6

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Parallax *Coefficient.*	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	*s*				σ
49 (87)	11	.7198	.6913	191	−35	110	.7311	− 41	+.0740	−0.648	57.7927
50	1	.8328	.8330	229	−34	110	.8622	+115	−.1125	−0.818	58.7507
	2	.8461	.8266	225	−35	108	.8650	+134	−.1117	− .798	.7565
(43)	3	.8240	.8310	245	−35	108	.8581	+ 98	−.1117	− .798	.7460
	6	.7042	.7006	292	−34	110	.7380	+ 52	−.0040	− .447	.7335
	9	.6356	.6495	272	−35	108	.6759	− 26	+.0858	− .773	.7492
	10	.6264	.6376	206	−36	106	.6584	− 24	+.0872	− .732	.7338
	11	.6362	.6416	197	−36	108	.6646	− 42	+.0877	− .714	.7389
	12	.6252	.6469	217	−36	108	.6637	− 35	+.0877	− .714	.7387
	13	.6383	.6366	239	−36	108	.6674	− 8	+.0877	− .714	.7451
	15	.5651	.5525	231	+36	110	.5953	− 61	+.1389	+ .623	.7361
	16	.5421	.5413	350	+34	112	.5901	− 39	+.1418	+ .494	.7343
	17	.5392	.5627	292	+34	112	.5935	− 42	+.1418	+ .494	.7374
	18	.5536	.5380	341	+34	110	.5931	− 31	+.1421	+ .481	.7383
	19	.5278	.5230	285	+34	108	.5669	− 19	+.1421	+ .481	.7133
	20	.5624	.5660	242	+34	108	.6014	− 73	+.1421	+ .481	.7424
						Mean					58.7396
51 (42)	2	.8800	.9059	340	−63	118	.9249	+243	−.0074	−0.409	106.9365
52	1	.3976	.3860	312	−45	137	.4295	+149	−.1365	−0.883	76.2966
	2	.3822	.3992	306	−45	136	.4277	+174	−.1355	− .869	.2984
(45)	3	.3848	.4191	339	−45	136	.4422	+127	−.1355	− .869	.3082
	10	.1701	.1525	277	−46	136	.1953	− 31	+.1061	− .818	.2878
	11	.1598	.1582	263	−47	136	.1915	− 54	+.1067	− .802	.2825
	12	.1513	.1481	293	−46	136	.1853	− 46	+.1067	− .802	.2771
	13	.1288	.1570	334	−46	136	.1826	− 10	+.1067	− .802	.2780
	15	.0628	.0610	299	+46	140	.1077	− 80	+.1689	+ .729	.2780
	16	.0323	.0501	446	+44	136	.1011	− 51	+.1725	+ .611	.2763
	18	.0378	.0366	435	+44	136	.0960	− 41	+.1729	+ .599	.2725
						Mean					76 2855
53	1	.0292	.0332	338	−44	136	.0715	+148	−.1840	−0.969	75.8899
	2	.0322	.0274	326	−45	136	.0688	+173	−.1827	− .970	.8909
(2)	3	.0089	.0216	375	−45	136	.0592	+127	−.1827	− .970	.8767
	6	.8531	.8279	499	−44	140	.8973	+ 68	−.0066	− .798	.8873
	7	.8662	.8756	411	−43	136	.9186	+ 70	−.0058	− .778	.9098
	9	.6960	.7096	452	−45	136	.7544	− 34	+.1411	− .968	.8797
	10	.7138	.7182	288	−46	136	.7511	− 31	+.1433	− .957	.8790
	11	.7125	.7225	269	−46	136	.7507	− 54	+.1441	− .952	.8772
	12	.7044	.7109	310	−46	136	.7449	− 45	+.1441	− .952	.8723
	13	.7131	.7071	363	−46	136	.7527	− 10	+.1441	− .952	.8836
	15	.5971	.5812	281	+46	140	.6332	− 79	+.2283	+ .927	.8655
	16	.5842	.5820	382	+44	140	.6370	− 51	+.2331	+ .848	.8759
	17	.5973	.5906	333	+44	140	.6430	− 54	+.2331	+ .848	.8816
	18	.5763	.5611	376	+44	138	.6218	− 41	+.2336	+ .838	.8621
	19	.5838	.5694	333	+44	134	.6248	− 25	+.2336	+ .838	.8667
	20	.5980	.5938	292	+44	136	.6404	− 94	+.2336	+ .838	.8754
						Mean					75.8796

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle π
	° ′ ″	′ ″	′ ″	″	′ ″	′		° ′ ″
11	204 39 45	41 48	14 13	− 6	54 54	− 8 53	+ 95	114 46 4.0
1	199 0 26	1 14	12 2	−15	12 37	+10 3	+ 66	109 23 46
2	198 58 34	59 32	13 28	−13	12 18	+10 28	+ 71	24 12
3	59 36	1 17	13 34	−20	13 41	+10 28	+ 71	24 41
6	199 12 8	13 4	11 38	−39	23 35	+ 0 23	+ 107	24 53
9	18 10	18 50	14 30	−33	32 27	− 8 7	+ 76	24 17
10	18 23	18 46	13 7	− 8	31 34	− 8 14	+ 82	23 29
11	18 7	18 59	14 13	− 6	32 40	− 8 17	+ 85	24 23
12	16 8	15 50	15 35	−11	31 23	− 8 17	+ 85	23 48
13	17 48	18 55	13 8	−19	31 33	− 8 17	+ 85	24 11
15	25 28	27 22	12 13	− 1	38 37	−13 8	−100	24 34
16	26 21	28 21	10 58	+ 7	38 26	−13 25	−109	23 53
17	28 37	29 22	11 10	+ 2	40 12	−13 25	−109	24 3
18	27 32	27 36	11 3	+ 3	38 40	−13 27	−109	23 44
19	26 53	27 40	11 22	+ 2	38 41	−13 27	−109	24 34
20	24 43	26 12	12 38	− 1	38 5	−13 27	−109	24 13
				Mean				109 24 10.7
2	229 19 12	20 3	13 28	− 9	32 57	+ 6 48	+ 61	139 41 7.0
1	191 1 24	2 38	12 2	−14	13 49	+ 7 20	+ 39	101 21 36
2	190 59 52	0 53	13 28	−12	13 38	+ 7 17	+ 43	22 10
3	191 0 5	1 12	13 34	−18	13 54	+ 7 17	+ 43	21 32
10	14 25	15 6	13 7	− 7	27 46	− 5 44	+ 53	22 0
11	13 8	13 45	14 13	− 5	27 35	− 5 46	+ 55	21 38
12	11 20	11 38	15 35	− 9	26 55	− 5 46	+ 55	21 40
13	13 55	14 13	13 8	−17	26 55	− 5 46	+ 55	21 53
15	18 23	19 38	12 13	+ 2	31 15	− 9 9	− 68	21 23
16	20 32	20 28	10 58	+14	31 42	− 9 21	− 76	21 25
18	18 40	20 4	11 3	+11	30 36	− 9 22	− 76	19 57
				Mean				101 21 31.4
1	170 48 12	48 55	12 2	− 5	0 31	+ 4 47	+ 7	81 5 34
2	46 22	46 50	13 28	− 5	59 59	+ 4 45	+ 11	5 48
3	47 0	48 15	13 34	− 8	1 4	+ 4 45	+ 11	5 59
6	53 52	53 47	11 38	−20	5 8	+ 0 10	+ 52	5 54
7	49 3	49 42	12 52	−11	2 3	+ 0 9	+ 54	5 52
9	55 12	56 25	14 30	−17	10 1	− 3 41	+ 16	5 56
10	56 10	56 38	13 7	− 2	9 29	− 3 45	+ 22	5 31
11	55 16	56 45	14 13	− 2	10 12	− 3 46	+ 25	6 4
12	53 20	54 3	15 35	− 4	9 13	− 3 46	+ 25	5 47
13	56 6	56 52	13 8	− 7	9 30	− 3 46	+ 25	6 17
15	59 44	0 28	12 13	+ 9	12 28	− 5 59	− 39	5 56
16	171 1 32	2 18	10 58	+29	13 22	− 6 6	− 52	6 28
17	1 52	3 37	11 10	+20	14 14	− 6 6	− 52	5 44
18	1 17	1 6	11 3	+27	12 42	− 6 7	− 52	5 26
19	0 10	0 48	11 22	+17	12 8	− 6 7	− 52	5 41
20	170 58 45	59 57	12 38	+11	12 10	− 6 7	− 52	5 58
				Mean				81 5 52.2

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Parallax *Coefficient.*	Final Corrected Distance.
		East	West.	Refrac.	Aberr.	Scale.	s				σ
54	1	.4460	.4362	344	—45	137	.4820	+151	—.1890	—0.972	77.2956
	2	.4637	.4137	333	—46	135	.4806	+176	—.1876	— .975	.2981
(3)	3	.4183	.4360	385	—46	134	.4716	+129	—.1876	— .975	.2844
	9	.0746	.0985	468	—46	134	.1393	— 34	+.1449	— .975	.2683
	10	.0965	.1053	294	—47	134	.1362	— 31	+.1472	— .969	.2679
	11	.0990	.0974	274	—47	134	.1315	— 55	+.1480	— .964	.2616
	12	.0802	.0902	316	—47	134	.1227	— 46	+.1480	— .964	.2537
	13	.0853	.0943	372	—47	134	.1329	— 10	+.1480	— .964	.2675
	15	.9911	.9729	227	+47	130	.0196	— 81	+.2344	+ .946	.2570
	16	.9606	.9866	375	+45	135	.0263	— 52	+.2394	+ .873	.2717
	17	.9814	.9784	330	+45	135	.0281	— 55	+.2394	+ .873	.2732
	18	.9590	.9661	373	+45	134	.0150	— 41	+.2398	+ .864	.2618
	20	.9690	.9765	293	+45	135	.0172	— 96	+.2398	+ .864	.2585
						Mean					77.2707
55	12	.6444	.6202	416	—82	17	.6525	— 81	—.0089	—0.194	134.6330
	13	.5973	.5996	417	—82	17	.6186	— 17	—.0089	— .194	.6055
(59)	18	.6110	.5766	670	+79	20	.6557	— 72	—.0146	— .108	.6325
						Mean					134.6237
56	2	.3874	.3912	474	—69	130	.4329	+267	—.2077	—0.833	117.2412
	3	.3788	.3658	541	—69	126	.4222	+196	—.2077	— .833	.2234
(6)	11	.0598	.0434	398	—71	122	.0867	— 84	+.1639	— .908	.2305
	15	.9152	.9111	354	+71	124	.9584	—122	+.2597	+ .979	.2185
	16	.8690	.8820	360	+68	124	.9210	— 78	+.2653	+ .993	.1913
	18	.8900	.8905	372	+68	124	.9368	— 63	+.2658	+ .993	.2091
	19	.8798	.8847	368	+68	124	.9285	— 38	+.2658	+ .993	.2033
						Mean					117.2168
57 (53)	2	.7927	.7629	445	—64	122	.8204	+245	—.2098	—0.881	107.6238
58	2	.8308	.8107	349	—53	138	.8597	+205	—.1171	—0.815	89.7526
	10	.6051	.6227	316	—55	138	.6493	— 37	+ 0917	— .752	.7276
(47)	11	.6066	.6086	303	—55	134	.6414	— 64	+.0922	— .735	.7178
	12	.5642	.5797	336	—55	134	.6091	— 54	+.0922	— .735	.6865
	13	.6056	.6115	374	—55	134	.6496	— 12	+.0922	— .735	.7312
	15	.5336	.5150	353	+54	135	.5741	— 94	+.1459	+ .649	.7189
	16	.5061	.5177	533	+52	137	.5797	— 60	+.1490	+ .521	.7294
	18	.4881	.4839	519	+52	135	.5522	— 48	+.1493	+ .508	.7032
	20	.5215	.5150	371	+52	132	.5693	—111	+.1493	+ .508	.7140
						Mean					89.7201

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Corrections plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient*.	Final Corrected Angle. *π*
1	167° 59′ 33″	0′ 3″	12′ 2″	— 4″	11′ 46″	+ 4′ 18″	+ 2	78° 16′ 18″
2	56 40	57 8	13 28	— 3	10 19	+ 4 16	+ 6	15 37
3	57 56	58 47	13 34	— 6	11 50	+ 4 16	+ 6	16 14
9	168 4 55	5 15	14 30	—14	19 21	— 3 18	+ 11	15 37
10	5 39	7 8	13 7	— 2	19 29	— 3 22	+ 17	15 52
11	5 12	6 10	14 13	— 1	19 53	— 3 23	+ 20	16 6
12	2 52	3 53	15 35	— 3	18 54	— 3 23	+ 20	15 49
13	5 55	6 20	13 8	— 6	19 10	— 3 23	+ 20	16 18
15	8 37	10 20	12 13	— 7	21 34	— 5 22	— 34	15 41
16	10 10	11 55	10 58	+31	22 31	— 5 28	— 46	16 17
17	12 2	13 53	11 10	+21	24 28	— 5 28	— 46	16 38
18	9 24	10 24	11 3	+28	21 25	— 5 29	— 47	14 49
20	8 30	9 18	12 38	+ 12	21 44	— 5 29	— 47	16 12
				Mean				78 15 57.5
12	234 16 10	16 58	15 35	— 7	32 2	— 4 17	+ 52	144 28 15
13	18 53	20 5	13 8	— 9	32 28	— 4 17	+ 52	28 54
18	24 55	25 28	11 3	—27	36 36	— 6 56	— 54	28 31
				Mean				144 28 33.3
2	132 39 28	40 15	13 28	+11	53 31	— 0 52	— 32	42 53 27
3	40 56	41 2	13 34	+16	54 49	— 0 52	— 32	53 51
11	39 11	39 40	14 13	+ 6	53 45	+ 0 41	— 25	53 46
15	40 7	40 53	12 13	+ 9	52 52	+ 1 5	+ 16	53 44
16	41 32	42 5	10 58	+20	53 6	+ 1 6	+ 7	53 46
18	40 40	41 35	11 3	+20	52 31	+ 1 7	+ 6	52 50
19	40 16	40 50	11 22	+14	52 9	+ 1 7	+ 6	53 17
				Mean				42 53 31.6
2	138 30 38	32 40	13 28	+10	45 17	— 0 16	— 29	48 45 51.0
2	197 16 8	16 14	13 28	—12	29 27	+ 6 45	+ 44	107 37 28
10	29 3	30 16	13 7	— 8	42 39	— 5 18	+ 52	37 19
11	28 26	28 22	14 13	— 5	42 32	— 5 20	+ 54	37 0
12	26 57	27 23	15 35	—10	42 35	— 5 20	+ 54	37 45
13	29 3	29 25	13 8	—19	42 3	— 5 20	+ 54	37 26
15	34 12	35 23	12 13	+ 1	47 2	— 8 27	— 64	37 53
16	35 58	36 52	10 58	+ 7	47 38	— 8 38	— 70	37 58
18	34 41	35 58	11 3	+ 5	46 28	— 8 39	— 71	36 33
20	32 46	34 18	12 38	+ 1	46 11	— 8 39	— 71	37 20
				Mean				107 37 24.4

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist		Corrections for			Corrected Mean. s	Scale Variation.	Proper Motion.	Parallax *Coefficient.*	Final Corrected Distance. σ
		East	West.	Refrac.	Aberr.	Scale.					
59	1	.9381	.9276	369	—57	148	.9731	+189	—.1024	—0.787	96.8795
	2	.9478	.9312	364	—57	148	.9793	+221	—.1017	— .767	.8899
(41)	3	.9334	.9322	394	—57	148	.9756	+162	—.1017	— .767	.8803
	10	.7559	.7671	337	—59	148	.7985	— 39	+.0796	— .695	8653
	11	.7572	.7653	323	—59	148	.7967	— 69	+.0800	— .676	.8611
	12	.7542	.7318	350	—59	148	.7812	— 58	+.0800	— .676	.8467
	13	.7580	.7381	388	—59	148	.7901	— 12	+.0800	— .676	.8602
	15	.6890	.6809	380	+59	146	.7379	—101	+.1266	+ .579	.8618
	16	.6440	.6572	581	+56	146	.7232	— 65	+.1293	+ .446	.8517
	17	.6586	.6644	482	+56	147	.7244	— 69	+.1293	+ .446	.8525
	18	.6513	.6443	564	+56	146	.7188	— 52	+.1296	+ .433	.8488
	19	.6702	.6610	471	+56	148	.7275	— 32	+.1296	+ .433	.8595
	20	.6762	.6707	399	+56	146	.7279	—120	+.1296	+ .433	.8511
						Mean					96.8622
60	2	.7962	.7690	422	—58	145	.8276	+222	—.2024	—0.968	97.6350
	13	.4324	.4264	473	—60	146	.4795	— 13	+.1597	— .985	.6253
(51)	15	.3186	.3134	338	+59	146	.3645	—102	+.2530	+ .998	.6201
						Mean					97.6268
61	1	.3070	.3036	397	—63	122	.3432	+211	—.0862	—0.737	108.2686
	2	.3178	.3030	389	—64	122	.3473	+246	—.0856	— .712	.2772
(40)	3	.3112	.2954	423	—64	122	.3436	+180	—.0856	— .712	.2669
	5	.2298	.2492	408	—62	120	.2784	+ 48	—.0031	— .323	.2760
	6	.2046	.2209	480	—62	122	.2591	+ 97	—.0031	— .323	.2616
	7	.2193	.1991	442	—61	120	.2515	+101	—.0027	— .295	.2551
	9	.1560	.1612	454	—65	126	.2024	— 48	+.0658	— .681	.2547
	10	.1578	.1520	368	—66	126	.1900	— 44	+.0669	— .633	.2444
	11	.1635	.1619	356	—66	126	.1966	— 77	+.0673	— .613	.2483
	12	.1466	.1568	383	—66	126	.1883	— 65	+.0673	— .613	.2412
	13	.1485	.1453	415	—66	126	.1867	— 14	+.0673	— .613	.2447
	15	.0917	.0877	425	+66	122	.1433	—113	+.1064	+ .506	.2449
	16	.0790	.0780	647	+63	122	.1540	— 72	+.1087	+ .367	.2602
	17	.0733	.0785	537	+63	122	.1404	— 77	+.1087	+ .367	.2461
	18	.0579	.0615	628	+63	122	.1333	— 58	+.1089	+ .354	.2409
	19	.0782	.0768	524	+63	122	.1407	— 35	+.1089	+ .354	.2506
	20	.0894	.0866	445	+63	122	.1433	—134	+.1089	+ .354	.2433
						Mean					108.2544
62	2	.5976	.6115	483	—66	125	.6504	+265	—.1918	—0.977	111.4726
	3	.5722	.5680	504	—66	124	.6179	+186	—.1918	— .977	.4322
(57)	18	.1430	.1066	539	+65	130	.1899	— 60	+.2453	+ .886	.4406
						Mean					111.4485

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac	Corrected Mean *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	′ ″	′ ″		° ′ ″
1	202 13 14	14 32	12 2	−16	25 39	+6 38	+43	112 32 45
2	11 48	13 5	13 28	−14	25 40	+6 35	+46	33 32
3	12 44	14 37	13 34	−20	26 55	+6 35	+46	33 53
10	25 8	25 22	13 7	−8	38 14	−5 10	+53	33 2
11	23 46	24 18	14 13	−6	38 9	−5 12	+54	32 45
12	21 55	23 7	15 35	−11	37 55	−5 12	+54	33 13
13	24 20	25 4	13 8	−19	37 53	−5 12	+54	33 24
15	29 20	30 35	12 13	−2	42 9	−8 15	−63	33 12
16	30 13	31 50	10 58	+2	42 2	−8 25	−68	32 44
17	32 40	33 57	11 10	−1	44 27	−8 25	−68	33 33
18	30 18	31 20	11 3	0	41 52	−8 26	−69	32 11
19	30 15	31 5	11 22	−2	42 00	−8 26	−69	33 8
20	28 45	29 52	12 38	−3	41 53	−8 26	−69	33 16
				Mean				112 33 7.5
2	156 50 25	50 51	13 28	+2	4 8	+2 3	−9	67 7 8
13	53 37	54 41	13 8	+1	7 18	−1 37	+1	6 5
15	56 2	58 2	12 13	+11	9 26	−2 34	−13	6 28
				Mean				67 6 33.7
1	207 10 48	12 2	12 2	−16	23 11	+6 12	+43	117 29 51
2	8 43	9 52	13 28	−14	22 31	+6 9	+45	29 56
3	9 24	11 10	13 34	−20	23 31	+6 9	+45	30 2
5	18 0	19 2	11 38	−17	29 52	+0 13	+62	30 19
6	17 4	18 27	11 38	−37	28 46	+0 13	+62	29 38
7	12 40	13 33	12 52	−26	26 33	+0 12	+62	30 28
9	20 16	21 4	14 30	−32	34 38	−4 46	+48	29 39
10	21 2	21 36	13 7	−8	34 18	−4 50	+52	29 26
11	19 56	20 56	14 13	−6	34 33	−4 52	+53	29 29
12	18 13	18 35	15 35	−11	33 48	−4 52	+53	29 26
13	20 33	21 8	13 8	−19	33 39	−4 52	+53	29 30
15	25 25	26 33	12 13	−3	38 9	−7 42	−60	29 46
16	26 32	28 16	10 58	−3	38 19	−7 52	−63	29 35
17	28 15	29 31	11 10	−6	39 57	−7 52	−63	29 37
18	26 20	26 53	11 3	−6	37 40	−7 53	−63	28 34
19	26 15	26 40	11 22	−3	37 47	−7 53	−63	29 30
20	24 26	25 40	12 38	−3	37 38	−7 53	−63	29 36
				Mean				117 29 40.1
2	165 20 35	21 26	13 28	−2	34 27	+2 42	+1	75 38 9
3	21 48	22 25	13 34	−4	35 37	+2 42	+1	38 25
18	30 0	30 27	11 3	+29	41 45	−3 28	−30	37 16
				Mean				75 37 56.7

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Concluded.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Parallax *Coefficient.*	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	*s*				σ
63	2	.7541	.7438	470	—65	133	.7946	+250	—.1809	—0.967	109.6263
	11	.4323	.4440	389	—67	133	.4757	— 78	+.1426	— .946	.5984
(48)	13	.4072	.4136	524	—67	126	.4607	— 14	+.1426	— .946	.5898
	15	.3026	.2808	411	+66	124	.3438	—114	+.2259	+ .920	.5701
	16	.2991	.3042	555	+61	128	.3683	— 73	+.2307	+ .837	.6024
	17	.2860	.2935	488	+	128	.3498	— 78	+.2307	+ .837	.5834
	18	.2766	.2810	550	+63	126	.3447	— 59	+.2312	+ .829	.5806
	19	.3023	.2725	483	+63	126	.3466	— 36	+.2312	+ .829	.5848
	20	.3147	.2970	425	+63	134	.3600	—136	+.2312	+ .829	.5882
						Mean					109.5916
64	1	.1776	.1780	535	—70	123	.2260	+234	—.2010	—0.965	120.0360
	2	.1922	.1778	520	—71	123	.2316	+273	—.1996	— .974	.0468
(46)	3	.1634	.1586	602	—71	123	.2157	+200	—.1996	— .974	.0236
	4	.0126	.9952	575	—73	123	.0558	— 3	—.0149	— .971	.0281
	5	.0018	.9997	558	—69	123	.0514	+ 53	—.0072	— .889	.0381
	6	.9536	.9504	818	—69	123	.0286	+107	—.0072	— .889	.0207
	7	.9913	.0029	664	—68	124	.0585	+111	—.0064	— .874	.0520
	9	.8060	.8200	741	—72	123	.8816	— 53	+.1542	— .981	.0179
	10	.8454	.8412	457	—73	123	.8834	— 49	+.1566	— .985	.0225
	11	.8628	.8512	427	—73	123	.8941	— 86	+.1575	— .984	.0304
	12	.8466	.8533	492	—73	123	.8936	— 72	+.1575	— .984	.0313
	13	.8351	.8323	584	—73	123	.8865	— 15	+.1575	— .984	.0299
	15	.7124	.7110	422	+73	123	.7629	—125	+.2495	+ .989	.0126
	17	.6883	.6890	477	+70	124	.7451	— 85	+.2548	+ .935	.0034
	19	.6955	.6875	481	+70	123	.7484	— 39	+.2553	+ .929	.0117
	20	.6944	.6862	434	+70	126	.7428	—149	+.2553	+ .929	.995[illegible]
						Mean					120.0250
65	2	.0835	.0878	479	—76	34	.1161	+294	—.0945	—0.743	129.0415
	15	.8134	.8004	506	+78	46	.8567	—135	+.1179	+ .547	128.9681
(50)	18	.7827	.7731	749	+75	43	.8515	— 69	+.1206	+ .398	.9703
	20	.8129	.8114	532	+75	43	.8641	—160	+.1206	+ .398	.9738
						Mean					128.9884
66	2	.9326	.9067	523	—72	122	.9659	+277	—.1821	—0.970	121.7990
	11	.6092	.6052	433	—75	123	.6443	— 87	+.1437	— .950	.7671
(49)	13	.6028	.5993	585	—75	122	.6532	— 16	+.1437	— .950	.7831
	18	.4338	.4378	610	+70	128	.5056	— 65	+.2329	+ .836	.7427
						Mean					121.7730

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Concluded.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle *π*
	° ′ ″	′ ″	′ ″	″	′ ″	′ ″		° ′ ″
2	171 47 50	48 36	13 28	− 5	1 36	+ 3 25	+ 8	82 6 4
11	54 45	55 13	14 13	− 2	9 10	− 2 42	+ 19	6 4
13	54 32	55 23	13 8	− 2	8 4	− 2 42	+ 19	5 53
15	57 35	59 8	12 13	+ 8	10 43	− 4 17	− 29	5 57
16	58 45	00 32	10 58	+30	10 6	− 4 23	− 37	5 1
17	172 0 50	1 45	11 10	+19	12 47	− 4 23	− 37	6 6
18	171 58 36	59 25	11 3	+28	10 32	− 4 23	− 38	5 5
19	58 36	59 6	11 22	+17	10 30	− 4 23	− 38	5 52
20	57 8	58 32	12 38	+ 10	10 38	− 4 23	− 38	6 15
				Mean				82 5 48.6
1	159 29 58	30 42	12 2	+ 1	42 23	+ 1 57	− 7	69 44 31
2	27 58	28 33	13 28	+ 1	41 45	+ 1 56	− 4	44 40
3	28 30	29 42	13 34	0	42 40	+ 1 56	− 4	44 41
4	30 58	31 25	12 39	0	43 51	+ 0 9	+ 10	43 29
5	32 37	32 45	11 38	0	44 19	+ 0 4	+ 23	44 23
6	31 30	33 2	11 38	− 6	43 48	+ 0 4	+ 23	44 17
7	27 32	27 55	12 52	− 8	40 28	+ 0 4	+ 25	44 2
9	31 23	31 55	14 30	− 4	46 5	− 1 30	− 1	44 5
10	32 38	33 35	13 7	+ 1	46 15	− 1 32	+ 2	44 23
11	31 37	32 12	14 13	+ 1	46 8	− 1 32	+ 4	44 6
12	29 26	30 7	15 35	+ 2	45 23	− 1 32	+ 4	44 3
13	31 28	32 32	13 8	+ 1	45 9	− 1 32	+ 4	44 2
15	34 5	35 40	12 13	+ 11	47 16	− 2 26	− 13	44 26
17	37 0	37 53	11 10	+ 23	49 0	− 2 29	− 21	44 18
19	34 50	35 2	11 22	+20	46 38	− 2 29	− 22	44 0
20	33 28	34 33	12 38	+13	46 52	− 2 29	− 22	44 29
				Mean				69 44 14.7
2	204 24 48	25 48	13 28	−14	38 32	+ 5 3	+ 36	114 44 48
15	39 12	40 48	12 13	− 3	52 10	− 6 20	− 49	45 13
18	40 5	41 10	11 3	− 2	51 39	− 6 28	− 52	44 2
20	38 30	39 10	12 38	− 3	51 25	− 6 29	− 52	44 51
				Mean				114 44 43.5
2	171 6 10	7 7	13 28	− 5	20 1	+ 3 1	+ 7	81 24 4
11	11 43	12 37	14 13	− 2	26 21	− 2 23	+ 16	23 33
13	12 10	12 34	13 8	− 7	25 23	− 2 23	+ 16	23 30
18	15 34	16 12	11 3	+ 28	27 24	− 3 52	− 33	22 30
								81 23 24.2

TABLE VII.—FOR PROPER MOTION.

(See Paragraphs 11–12 and 17–18.)

Star No.	In Distance.		In Position Angle.		
	S_1	S_3	S_5	S_6	S_7
1	—.2384	—.0035	+.9712	.007 43	+.007 216
2	—.9977	—.0000	+.0681	.009 17	+.000 624
3	—.9997	—.0000	—.0237	.008 75	—.000 207
4	—.9968	—.0000	—.0794	.009 03	—.000 717
5	—.7484	—.0029	+.6632	.012 95	+.008 588
6	—.9997	—.0000	—.0228	.010 53	—.000 240
7	—.9979	—.0000	+.0649	.012 29	+.000 798
8	—.3231	—.0073	+.9464	.016 36	+.015 483
9	—.8917	—.0009	—.4526	.008 72	—.003 947
10	+.1802	—.0049	+.9836	.010 09	+.009 925
11	+.1589	—.0066	+.9873	.013 48	+.013 309
12	—.0319	—.0093	+.9995	.018 63	+.018 621
13	+.3395	—.0045	+.9406	.010 17	+.009 566
14	—.4216	—.0118	+.9068	.028 84	+.026 152
15	—.9606	—.0007	—.2780	.019 16	—.005 326
16	—.9419	—.0019	+.3360	.033 01	+.011 091
17	+.3379	—.0054	+.9412	.012 13	+.011 417
18	+.2877	—.0065	+.9577	.014 30	+.013 695
19	—.7295	—.0018	—.6840	.007 76	—.005 308
20	+.4677	—.0053	+.8838	.013 56	+.011 984
21	—.9264	—.0032	—.3767	.044 91	—.016 918
22	+.5569	—.0031	+.8306	.009 04	+.007 509
23	+.5665	—.0038	+.8240	.011 20	+.009 229
24	+.1855	—.0568	+.9827	.117 38	+.115 349
25					
26					
27	—.5863	—.0085	—.8100	.026 06	—.021 109
28	—.6038	—.0028	—.7971	.008 95	—.007 134
29	+.7608	—.0058	+.6488	.027 76	+.018 011
30	+.9269	—.0039	+.3753	.054 36	+.020 401
31	—.4932	—.0063	—.8699	.016 70	—.014 527
32	—.5183	—.0048	—.8552	.013 00	—.011 118
33	+.8631	—.0037	+.5049	.028 72	+.014 501
34	—.0903	—.0144	—.9959	.028 99	—.028 871
35	+.3090	—.0200	—.9510	.044 16	—.041 996
36	+.8577	—.0059	—.5141	.044 64	—.022 941
37	—.1433	—.0103	—.9897	.020 95	—.020 734
38	—.4283	—.0036	—.9036	.008 91	—.008 051
39	+.7852	—.0017	+.6192	.008 79	+.005 443
40	—.3641	—.0045	—.9314	.010 39	—.009 677

TABLE VII.—FOR PROPER MOTION. (*Concluded.*)

(See Paragraphs 11–12 and 17–18.)

Star No.	In Distance.		In Position Angle.		
	S_1	S_2	S_5	S_6	S_7
41	+.3234	—.0132	—.9463	.029 42	—.027 840
42	+.8099	—.0014	+.5866	.008 12	+.004 763
43	—.0424	—.0077	—.9991	.015 35	—.015 336
44	+.1342	—.0086	—.9909	.017 50	—.017 341
45	+.8777	—.0011	+.4792	.009 43	+.004 519
46	+.8362	—.0034	—.5484	.022 47	—.012 323
47	—.3107	—.0035	—.9505	.007 66	—.007 281
48	+.5812	—.0065	—.8137	.019 69	—.016 022
49	+.4478	—.0069	—.8941	.017 30	—.015 468
50	+.5301	—.0061	—.8479	.017 02	—.014 431
51	+.0343	—.0047	—.9994	.009 35	—.009 344
52	+.6442	—.0038	—.7648	.013 11	—.010 027
53	+.8692	—.0016	—.4943	.013 18	—.006 515
54	+.8926	—.0013	—.4508	.012 94	—.005 833
55	—.0531	—.0037	—.9986	.007 43	—.007 420
56	+.9887	—.0001	+.1500	.008 53	+.001 280
57	+.9988	—.0000	+.0482	.009 29	+.000 448
58	+.5565	—.0039	—.8309	.011 15	—.009 265
59	+.4832	—.0040	—.8755	.010 32	—.009 035
60	+.9632	—.0004	—.2689	.010 24	—.002 754
61	+.4063	—.0039	—.9137	.009 24	—.008 443
62	+.9128	—.0007	—.4084	.008 97	—.003 663
63	+.8604	—.0012	—.5096	.009 13	—.004 653
64	+.9498	—.0004	—.3129	.008 33	—.002 606
65	+.4494	—.0031	—.8933	.007 75	—.006 923
66	+.8669	—.0010	—.4984	.008 21	—.004 092

TABLE VIII.—FOR PARALLAX.

(See Paragraphs 14 and 22.)

Star No.	In Distance.		In Position Angle.	
	S_3	S_4	S_8	S_9
1	+.080	+.825	— 52.6	— 4.6
2	+.941	+.330	— 14.6	+ 51.4
3	+.957	+.259	— 8.3	+ 50.7
4	+.962	+.215	— 5.0	+ 53.2
5	+.613	+.726	— 71.1	+ 38.2
6	+.957	+.260	— 10.0	+ 61.1
7	+.941	+.328	— 19.3	+ 68.9
8	+.165	+.829	—114.6	— 1.3
9	+.918	—.106	+ 19.1	+ 52.8
10	—.320	+.718	— 67.6	— 30.8
11	—.301	+.727	— 90.9	— 39.7
12	—.121	+.790	—131.3	— 35.0
13	—.466	+.641	— 63.3	— 39.5
14	+.265	+.825	—197.3	+ 15.9
15	+.958	+.049	+ 17.0	+116.8
16	+.847	+.524	—112.7	+156.0
17	—.464	+.642	— 75.5	— 47.0
18	—.419	+.668	— 91.4	— 51.8
19	+.799	—.332	+ 31.0	+ 43.4
20	—.579	+.561	— 77.0	— 61.1
21	+.940	—.037	+ 73.1	+273.8
22	—.656	+.494	— 47.1	— 44.3
23	—.665	+.487	— 57.7	— 55.4
24	—.325	+.716	—779.8	—372.7
25				
26				
27	+.681	—.470	+131.6	+130.8
28	+.696	—.455	+ 44.1	+ 45.6
29	—.823	+.296	—102.8	—158.3
30	—.940	+.036	— 85.8	—331.6
31	+.602	—.543	+ 93.0	+ 76.9
32	+.623	—.524	+ 70.6	+ 61.4
33	—.899	+.155	— 74.0	—172.3
34	+.237	—.753	+199.8	+ 73.8
35	—.151	—.829	+309.6	+ 5.4
36	—.740	—.640	+203.1	—173.8
37	+.286	—.734	+142.3	+ 59.3
38	+.545	—.587	+ 52.3	+ 38.4
39	—.842	+.266	— 30.5	— 50.9
40	+.488	—.627	+ 63.7	+ 41.5

TABLE VIII.—FOR PARALLAX. (*Concluded.*)

(See Paragraphs 14 and 22.)

Star No.	In Distance.		In Position Angle.	
	S_3	S_4	S_8	S_9
41	—.165	—.829	+206.0	+ 2.0
42	—.861	+.234	— 26.1	— 47.6
43	+.192	—.769	+107.0	+ 34.9
44	+.022	—.812	+124.3	+ 21.8
45	—.909	+.131	— 22.5	— 56.8
46	—.714	—.660	+107.2	— 83.1
47	+.440	—.656	+ 48.5	+ 28.5
48	—.431	—.797	+125.1	— 33.3
49	—.292	—.823	+117.1	— 13.2
50	—.377	—.810	+111.3	— 22.6
51	+.118	—.790	+ 65.9	+ 17.4
52	—.498	—.776	+ 79.7	— 28.2
53	—.754	—.627	+ 58.4	— 52.6
54	—.783	—.600	+ 53.8	— 54.6
55	+.202	—.765	+ 51.7	+ 17.4
56	—.965	—.157	+ 0.4	— 51.1
57	—.959	—.240	+ 7.2	— 54.3
58	—.405	—.804	+ 71.9	— 16.9
59	—.328	—.818	+ 68.9	— 10.3
60	—.877	—.477	+ 30.3	— 51.1
61	—.249	—.827	+ 63.4	— 4.4
62	—.808	—.572	+ 34.8	— 39.6
63	—.743	—.637	+ 41.4	— 35.7
64	—.858	—.508	+ 27.1	— 40.2
65	—.293	—.823	+ 52.5	— 5.9
66	—.751	—.630	+ 36.6	— 32.6

TABLE IX.—MEAN RESULTS.

Star No.	Distance.	Position Angle.	α′—α	δ′—δ	No of Plates.	Durchmusterung.	
						No.	Mag.
	″	° ′ ″	″	″		°	
1	3771.42	307 44 19.4	—3824.94	+2291.19	10	38.4318	7.2
2	3055 07	235 25 23.3	—3176.65	—1745.70	6	37.4154	9.1
3	3202.47	230 9 10.8	—3101.33	—2063.32	5	37.4155	9.3
4	3103.85	226 58 31.0	—2861.47	—2127.48	2	37.4157	9.3
5	2163.15	273 6 36.6	—2746.93	+ 108.47	19	38.4325	6.0
6	2660.10	230 12 33.1	—2581.61	—1710.30	19	37.4159	7.5
7	2279.03	235 15 9.0	—2368.76	—1305 58	2	37.4161	9.5
8	1712.84	302 42 34.5	—1838.55	+ 921.62	6	38.4331	9.3
9	3213.79	204 35 20.2	—1681.35	—2925.69	6	37.4166	9.1
10	2775.08	332 1 31.7	—1670.41	+2447.56	6	38.4332	9.2
11	2078.41	330 48 8.3	—1297.85	+1812.35	3	38.4333	9.4
12	1503.97	319 53 21.3	—1237.16	+1148.44	3	38.4334	9 5
13	2754.25	341 24 38 4	—1127.39	+2609.07	17	38 4335	9.0
14	971.48	296 47 43.5	—1104.18	+ 436.52	11	38.4336	8.8
15	1462.27	215 20 57.0	—1070.60	—1194.04	8	37.4170	8.5
16	848.59	251 12 59 6	—1020.22	— 274.47	8	37.4171	9.4
17	2308 80	341 20 48.0	— 946.63	+2186.47	6	[38.4338]	[9.4]
18	1958.83	338 22 5.9	— 924 37	+1819 88	9	38.4337	9.0
19	3610.25	188 17 34.5	— 653.13	—3573.00	4	37.4172	8.3
20	2066.13	349 29 58.9	— 482.39	+2031.26	12	38.4339	8.9
21	623 86	209 16 22.4	— 386.98	— 544.37	7	37.4173	8.8
22	3100.22	355 24 41.4	— 319.06	+3090.17	7	38.4340	9.1
23	2500.62	356 4 29.8	— 219.69	+2494.70	19	38.4341	8.2
24	238.68	333 13 7.5	— 136.82	+ 213.06	2	38.4342	9.5
25		**61^1 Cygni**				38.4343	5.0
26	19.39	*61^2 Cygni*			19	38.4344	5.3
27	1074.60	177 15 24.0	+ 65.11	—1073.38	10	37.4175	9.0
28	3130.15	178 34 1.3	+ 98.35	—3129.18	6	37.4176	8.7
29	1008.91	11 4 37.0	+ 247.35	+ 990.04	3	38.4348	9.5
30	515.04	29 38 16.0	+ 324.32	+ 447.54	1	38.4349	9.4
31	1677.09	170 56 2.0	+ 333.84	—1656.26	1	37.4177	9.5
32	2155.55	172 40 30.0	+ 346.56	—2138.10	19	37.4178	7.5
33	975.29	21 15 9.1	+ 450 96	+ 908 72	7	38.4350	9.5
34	966.32	146 39 17.0	+ 673.17	— 807.78	3	37.	
35	634.19	123 8 22.5	+ 674.16	— 347.24	2	37.4179	8.6
36	627.41	82 19 26.8	+ 790.67	+ 83.07	8	38.4351	9.5
37	1336.94	149 37 6.6	+ 855.80	—1154.21	18	37.4180	7.7
38	3143.57	166 49 5.1	+ 900.87	—3061.70	9	37.4181	9.0
39	3185.45	13 17 8.6	+ 941.74	+3099.16	14	38.4353	8.4
40	2696.96	162 49 15.6	+1002.82	—2577.83	7	37.4182	9.4

TABLE X.—CATALOGUE OF STARS ABOUT 61^1 CYGNI.

Star No.	A.G. Lund.	Right Ascension, 1873.	Precession, *J*	Sec. Var., *K*	Declination, 1873.	Precession, *L*	Sec. Var., *M*
		h m s	s	s	° ′ ″	″	″
1		20 56 57.333	+2.3031	+0.0041	38 45 44.59	+13.991	+0.235
2		57 40.552	2.3357	.0041	37 38 27.70	14.036	.237
3		57 45.574	2.3384	.0041	37 33 10.08	14.041	.237
4		58 1.564	2.3396	.0041	37 32 5.92	14.058	.237
5		58 9.200	2.3235	.0042	38 09 21.87	14.066	.236
6		20 58 20.222	+2.3375	+0.0041	37 39 3.10	+14.077	+0.237
7		58 34.412	2.3353	.0042	37 45 47.82	14.092	.236
8		59 9.759	2.3206	.0042	38 22 55.02	14.129	.234
9		59 20.239	2.3496	.0042	37 18 47.71	14.140	.237
10		59 20.968	2.3097	.0043	38 48 20.96	14.140	.232
11		20 59 45.806	+2.3161	+0.0043	38 37 45.75	+14.166	+0.233
12		59 49.852	2.3211	.0043	38 26 41.84	14.170	.233
13		59 57.170	2.3107	.0043	38 51 2.47	14.178	.232
14		59 58.717	2.3270	.0043	38 14 49.92	14.179	.234
15		21 00 0.956	2.3391	.0042	37 47 39.36	14.181	.235
16		21 00 4.314	+2.3324	+0.0043	38 02 58.93	+14.185	+0.234
17		00 9.220	2.3145	.0043	38 43 59.87	14.190	.233
18		00 10.704	2.3172	.0044	38 37 53.28	14.192	.233
19		00 28.787	2.3578	.0043	37 08 0.40	14.210	.237
20		00 40.170	2.3172	.0044	38 41 24.66	14.222	.232
21		21 00 46.530	+2.3369	+0.0044	37 58 29.03	+14.229	+0.234
22		00 51.058	2.3099	.0044	38 59 3.57	14.233	.231
23		00 57.683	2.3149	.0044	38 49 8.10	14.240	.232
24		01 3.208	2.3321	.0044	38 11 6.46	14.246	.233
25		**21 01 12.329**	**2.3343**	**.0044**	**38 07 33.40**	**14.260**	**.233**
26			See	*Contribu*	*tion* No. 13.		
27		01 16.670	+2.3422	+0.0044	37 49 40.02	+14.259	+0.234
28		01 18.886	2.3572	.0044	37 15 24.22	14.262	.235
29		01 28.819	2.3276	.0044	38 24 3.44	14.272	.232
30		01 33.950	2.3321	.0044	38 15 0.94	14.277	.233
31		21 01 34.585	+2.3387	+0.0044	37 39 57.14	+14.278	+0.234
32		01 35.433	2.3511	.0044	37 31 55.30	14.279	.235
33		01 42.393	2.3290	.0044	38 22 42.12	14.286	.232
34		01 57.207	2.3425	.0044	37 54 5.62	14.301	.234
35		01 57.273	2.3392	.0044	38 01 46.16	14.301	.233
36		21 02 5.040	+2.3364	+0.0044	38 08 56.47	+14.309	+0.233
37		02 9.382	2.3458	.0044	37 48 19.19	14.313	.234
38		02 12.387	2.3597	.0044	37 16 31.70	14.316	.235
39		02 15.112	2.3147	.0045	38 59 12.56	14.319	.230
40		02 19.184	2.3565	.0044	37 24 35.57	14.324	.234

TABLE IX.—MEAN RESULTS. (*Concluded.*)

Star No.	Distance	Position Angle.			α′—α	δ′—δ	No. of Plates.	Durchmusterung.	
								No.	Mag.
	″	°	′	″	″	″		°	
41	952.00	122	36	30.0	+1017.45	— 514.25	2	37.4183	9.5
42	3448.83	15	37	11.8	+1195.67	+3319.79	5	38.4356	8.9
43	1824.90	143	50	53.3	+1360.90	—1475.72	12	37.4185	9.0
44	1600.46	133	45	6.3	+1463.45	—1109.29	6	37.4186	9.5
45	2971.02	22	53	48.0	+1484.97	+2734.35	2	38.4357	9.3
46	1246.52	84	39	5.0	+1578.37	+ 113.27	1	38.4358	9.5
47	3657.35	159	32	17.0	+1604.53	—3429.64	3	37.4187	9.0
48	1422.69	105	53	10.6	+1736.87	— 392.98	19	37.4189	7.9
49	1618.91	114	46	4.0	+1863.84	— 682.32	1	37.4191	9.4
50	1645.44	109	24	10.7	+1968.78	— 551.20	15	37.4192	9.0
51	2995.55	139	41	7.0	+2442.53	—2291.17	1	37.4195	9.5
52	2136.94	101	21	31.4	+2658.96	— 429.20	10	37.4197	9.1
53	2125.57	81	5	52.2	+2672.78	+ 320.52	16	38.4362	7.8
54	2164.54	78	15	57.5	+2698.53	+ 431.63	13	38.4363	9.1
55	3771.13	144	28	33.3	+2753.46	—3078.19	3	37.4198	8.7
56	3283.52	42	53	31.6	+2867.24	+2396.00	7	38.4364	9.0
57	3014.80	48	45	51.0	+2903.97	+1977.36	1	38.4365	9.3
58	2513.28	107	37	24.4	+3036.08	— 771.78	9	37.4201	9.3
59	2713.34	112	33	7.5	+3172.80	—1052.51	13	37.4202	8.8
60	2734.76	67	6	33.7	+3215.61	+1051.59	3	38.4367	9.0
61	3032.47	117	29	40.1	+3401.30	—1413.65	17	37.4203	8.3
62	3121.94	75	37	56.7	+3855.71	+ 757.20	3	38.4369	9.3
63	3069.92	82	5	48.6	+3871.48	+ 404.48	9	38.4370	9.0
64	3362.19	69	44	14.7	+4027.23	+1145.36	16	38.4372	7.8
65	3613.27	114	44	43.5	+4147.41	—1532.77	4	37.4209	8.4
66	3411.15	81	23	24.2	+4295.50	+ 488.97	4	38.4375	8.4

TABLE X.—CATALOGUE OF STARS ABOUT 61^1 CYGNI. (*Concluded.*)

Star No.	A.G. Lund.	Right Ascension, 1873.	Precession, *J*	Sec. Var., *K*	Declination, 1873.	Precession, *L*	Sec. Var., *M*
		h m s	s		° ′ ″	″	
41		21 02 20.159	+2.3415	+0.0045	37 58 59.15	+14.325	+0.233
42		02 32.040	2.3140	.0045	39 2 53.19	14.336	.230
43		02 43.056	2.3498	.0045	37 42 57.68	14.348	.234
44		02 49.892	2.3476	.0045	37 49 4.11	14.355	.233
45		02 51.327	2.3194	.0045	38 53 7.75	14.356	.230
46		21 02 57.554	+2.3391	+0.0045	38 9 26.67	+14.362	+0.232
47		02 59.298	2.3648	.0045	37 10 23.76	14.364	.235
48		03 8.120	2.3434	.0045	38 1 0.42	14.373	.232
49		03 16.585	2.3459	.0045	37 56 11.08	14.382	.232
50		03 23.581	2.3453	.0045	37 58 22.20	14.389	.232
51		21 03 55.164	+2.3595	+0.0045	37 29 22.23	+14.421	+0.233
52		04 9.593	2.3470	.0046	38 0 24.20	14.435	.231
53		04 10.514	2.3415	.0046	38 12 53.92	14.436	.231
54		04 12.231	2.3409	.0046	38 14 45.03	14.438	.231
55		04 15.893	2.3662	.0045	37 16 15.21	14.442	.233
56		21 04 23.478	+2.3272	+0.0046	38 47 29.40	+14.450	+0.229
57		04 25.927	2.3302	.0046	38 40 30.76	14.452	.230
58		04 34.734	2.3508	.0046	37 54 41.62	14.461	.232
59		04 43.849	2.3532	.0046	37 50 0.89	14.470	.232
60		04 46.703	2.3382	.0046	38 25 4.99	14.473	.230
61		21 04 59.082	+2.3567	+0.0046	37 43 59.75	+14.486	+0.231
62		05 29.376	2.3427	.0047	38 20 10.60	14.516	.230
63		05 30.428	2.3454	.0047	38 14 17.88	14.517	.230
64		05 40.811	2.3406	.0048	38 26 38.76	14.527	.229
65		05 48.823	2.3603	.0047	37 42 0.63	14.536	.231
66		05 58.696	2.3463	.0048	38 15 42.37	14.546	.229

TABLE XI.—LIMITING VALUES OF PARALLAX COEFFICIENTS FOR $\Pi = +0.''3597$.

IN DISTANCE.

Use Parallax Coefficient $S_3 P_3 + S_4 P_4$ as the argument in the body of table.

	d .0000	d .0010	d .0020	d .0030	d .0040	d .0050	d .0060	d .0070	d .0080	d .0090	d .0100	d .0110
	.0000	.0740	.1519	.2297	.3076	.3855	.4634	.5412	.6191	.6970	.7749	.8528
d .0000												
	.0039	.0818	.1596	.2375	.3154	.3933	.4712	.5490	.6269	.7048	.7827	.8605
1												
	.0117	.0896	.1674	.2453	.3232	.4011	.4789	.5568	.6347	.7126	.7905	.8683
2												
	.0195	.0973	.1752	.2531	.3310	.4089	.4867	.5646	.6425	.7204	.7982	.8761
3												
	.0273	.1051	.1830	.2609	.3388	.4166	.4945	.5724	.6503	.7282	.8060	.8839
4												
	.0350	.1129	.1908	.2687	.3466	.4244	.5023	.5802	.6581	.7359	.8138	.8917
5												
	.0428	.1207	.1986	.2765	.3543	.4322	.5101	.5880	.6658	.7437	.8216	.8995
6												
	.0506	.1285	.2064	.2843	.3621	.4400	.5179	.5958	.6736	.7515	.8294	.9073
7												
	.0584	.1363	.2142	.2920	.3699	.4478	.5257	.6035	.6814	.7593	.8372	.9151
8												
	.0662	.1441	.2219	.2998	.3777	.4556	.5335	.6113	.6892	.7671	.8450	.9228
.0009												
	.0740	.1519	.2297	.3076	.3855	.4634	.5412	.6191	.6970	.7749	.8528	.9306

IN POSITION-ANGLE.

Use Parallax Coefficient $S_8 P_3 + S_9 P_4$ as the argument in the body of table.

	00''	10''	20''	30''	40''	50''	60''	70''	80''	90''	100''
	0.0	26.4	54.2	82.0	109.8	137.6	165.4	193.2	221.0	248.8	276.6
0.''											
	1.4	29.2	57.0	84.8	112.6	140.4	168.2	196.0	223.8	251.6	279.4
1.											
	4.2	32.0	59.8	87.6	115.4	143.2	171.0	198.8	226.6	254.4	282.2
2.											
	7.0	34.8	62.6	90.4	118.2	146.0	173.8	201.6	229.4	257.2	285.0
3.											
	9.7	37.5	65.3	93.1	120.9	148.7	176.5	204.3	232.1	259.9	287.7
4.											
	12.5	40.3	68.1	95.9	123.7	151.5	179.3	207.1	234.9	262.7	290.5
5.											
	15.3	43.1	70.9	98.7	126.5	154.3	182.1	209.9	237.7	265.5	293.3
6.											
	18.1	45.9	73.7	101.5	129.3	157.1	184.9	212.7	240.5	268.3	296.1
7.											
	20.9	48.7	76.5	104.3	132.1	159.9	187.7	215.5	243.3	271.1	298.9
8.											
	23.6	51.4	79.2	107.0	134.8	162.6	190.4	218.2	246.0	273.8	301.6
9.											
	26.4	54.2	82.0	109.8	137.6	165.4	193.2	221.0	248.8	276.6	304.4

The Position of 61^2 Cygni.

26. When we correct the measured coördinates of 61^2 *Cygni* with respect to 61^1 *Cygni*, it is, of course, necessary to take into account the very considerable proper motion of the measured star as well as of the central star.

On account of the shortness of time over which the RUTHERFURD plates extend, a value of the relative motion deduced from them alone would have very small weight. On the other hand, the mean of the measured distances and of the measured angles is entitled to great weight as representing the true value of the distance and angle of these stars at the mean of the dates of observation, 1873.546. I have, accordingly, with the latter as a basis, deduced trigonometrically a set of formulæ which represent the motion of either of these stars relative to the other; assuming the motion of each to be uniform and on the arc of a great circle. In these formulæ have then been substituted constants derived from the proper motion of each star separately, as determined from meridian observations in the manner used in my "Declinations and Proper Motions of Fifty-six Stars,"* to which reference is made for an explanation of the method.

27. For 61^1 *Cygni* I have used AUWERS' values as previously quoted on page 62; but for 61^2 *Cygni* the results given here have been derived from the data of Table XII.

61^1 *Cygni* $\rho = 5.''20521 \quad \lambda = 51^\circ 38' 42'' \quad t = 1807.$
61^2 *Cygni* $\rho = 5. \;\; 15192 \quad \lambda = 53 \;\; 33 \;\; 47 \quad t = 1858.$

By the usual formulæ† these become:

61^1 *Cygni* $\rho_0 = 5.''20521 \quad \lambda_0 = 51^\circ 42' 13'' \quad 1873.546.$
61^2 *Cygni* $\rho_0' = 5. \;\; 15192 \quad \lambda_0' = 53 \;\; 34 \;\; 37 \quad 1873.546.$

We have also:

61^1 *Cygni* $\delta_0 = 38^\circ 7' 35''$

and from the RUTHERFURD measures:

For 61^2 *Cygni*, relative to 61^1, $\sigma_0 = 19.''3823 \quad \pi_0 = 114^\circ 41' 30''$ **at** $1873.546.$

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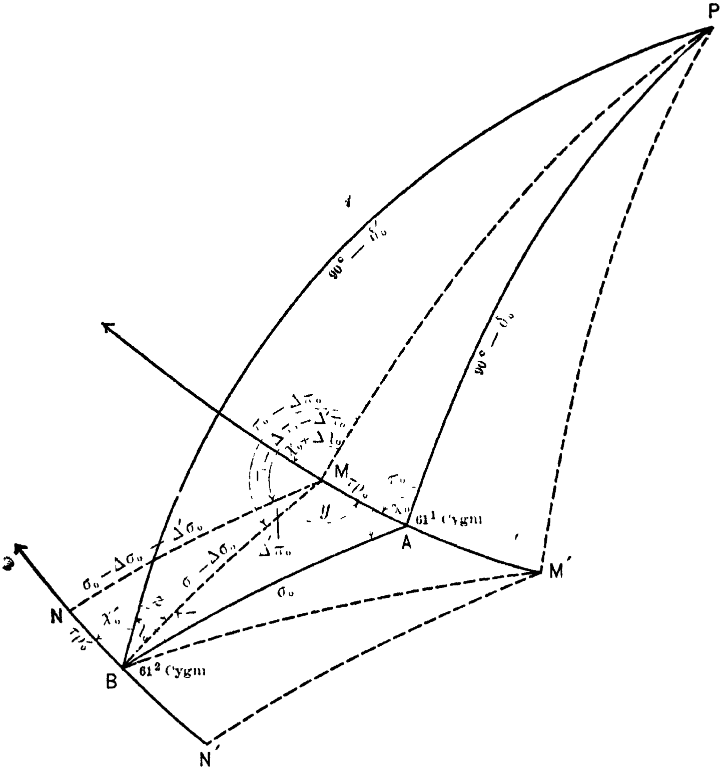
* *Contribution from the Observatory of Columbia College, New York.*—No. 8.

† Chauvenet: Manual of Spherical and Practical Astronomy, Vol. I, §380.



$AB = \sigma_0$ = True distance at 1873.546 from the mean of all the measured distances.

MN = Distance measured on plate of the date, t, corrected except for proper motion.

ρ_0, ρ_0' = The proper motions of 61¹ and 61² *Cygni* at the epoch 1873.546.

AM, BN = Arcs traveled over in the time $\tau = t - 1873.546$.

$\Delta\sigma_0$ = The change in σ_0 due to the proper motion of only *61*¹ from *A* to *M*.

$\Delta'\sigma_0$ = The change in $(\sigma_0 - \Delta\sigma_0)$ due to the proper motion of only *61*² from *B* to *N*.

$PAB = \pi_0$ = True angle at 1873.546 from the mean of all the measured angles.

PMN = Position-angle measured on plate of the date, t, corrected except for proper motion.

χ_0, χ_0' = The position-angles of the proper motion of *61*¹ and *61*² at 1873.546.

$PBA = \lambda_0'$, also y, z, λ are auxiliary angles having the significance shown above.

$\Delta\pi_0$ = The change in π_0 due to the proper motion of only *61*¹ from *A* to *M*.

$\Delta'\pi_0$ = The change in $(\pi_0 - \Delta\pi_0)$ due to the proper motion of *61*² from *B* to *N*.

28. Let the angles and arcs have the significance attached to them in the figure; where *P* is the Pole; *PA* and *PB* hour-circles through *61*^{1} and *61*^{2} respectively at 1873.546, and *M′M* and *N′N* the paths of proper motion. Then, as the arc *AB* joining *61*^{1} and *61*^{2} is the mean of all the measures of distance, it may be assumed as the true distance at the mean date of observation. In like manner *PAB* is assumed as the true position-angle at the same date. The problem before us is to (1) determine the distance *MN* at the end of the interval τ years; (2) determine the angle *PMN* at the end of the same interval. In both these cases evidently we regard the only cause of motion of the stars to be that known as proper motion, *i.e.*, uniform motion on the arc of a great circle.

Let all angles count from the hour circle positively towards the east, *i.e.*, counter-clockwise in the figure; or else from the arc *AB*, but always likewise positive when counter-clockwise, as shown by the direction of the arrows in the figure.

29. Let us first suppose that *61*^{2} remains motionless while *61*^{1} advances from *A* to *M* during the time τ; then the change in distance is given by the formula:

$$\begin{aligned}\Delta\sigma_0 = {} & (\tau\rho_0)\cos(\pi_0 - \lambda_0)\\ & + (\tau\rho_0)^2\left\{-\frac{1}{2\sigma_0}\sin^2(\pi_0-\lambda_0)\right\}\\ & + (\tau\rho_0)^3\left\{-\frac{1}{2\sigma_0^2}\sin^2(\pi_0-\lambda_0)\cos(\pi_0-\lambda_0)\right\}\\ & + (\tau\rho_0)^4\left\{\frac{1}{2\sigma_0^3}[\tfrac{1}{4}\sin^4(\pi_0-\lambda_0)-\sin^2(\pi_0-\lambda_0)\cos^2(\pi_0-\lambda_0)]\right\}.\end{aligned}$$

When the proper constants have been substituted in this we have:

$$\Delta\sigma_0 = [9.657224](\tau\rho_0)+[8.311234_n](\tau\rho_0)^2+[6.68105_n](\tau\rho_0)^3+[3.6310_n](\tau\rho_0)^4.$$

Thus is obtained the auxiliary distance *BM* agreeing of course with the formula of paragraph 11, as far as terms in τ^2.

30. Now during the same interval of time τ, suppose *61*^{1} to remain still and *61*^{2} to be in motion. Then the change of distance is given by the formula:

$$\begin{aligned}\Delta'\sigma_0 = {} & (\tau\rho_0')\cos(\lambda_0'-z)\\ & + (\tau\rho_0')^2\left\{-\frac{1}{2(\sigma_0-\Delta\sigma_0)}\sin^2(\lambda_0'-z)\right\}\\ & + (\tau\rho_0')^3\left\{-\frac{1}{2(\sigma_0-\Delta\sigma_0)^2}\sin^2(\lambda_0'-z)\cos(\lambda_0'-z)\right\}\\ & + (\tau\rho_0')^4\left\{\frac{1}{2(\sigma_0-\Delta\sigma_0)^3}[\tfrac{1}{4}\sin^4(\lambda_0'-z)-\sin^2(\lambda_0'-z)\cos^2(\chi_0'-z)]\right\}\end{aligned}$$

which may be computed for each plate separately after $\Delta\sigma_0$ has been computed by the preceding formula; and where the value of z is obtained from the following relations :*

$$\lambda_0' = 180^\circ - \pi_0 - \sigma_0 \sin \pi_0 \tan \delta_0$$

$$\cot \lambda = \frac{1}{\tau\rho_0} \frac{\sigma_0}{\sin(\pi_0 - \lambda_0)} - \cot(\pi_0 - \chi_0).$$

By substitution of the constants for these stars these become :

$$\lambda_0' = 65^\circ 18' 16''.5$$

$$\cot \lambda_0 = 21.75560 \frac{1}{\tau\rho_0} - 0.509789$$

hence

$$z = \lambda - 65^\circ 18' 16''.5$$

which may be computed for each plate.

Thus the variation in distance due solely to the proper motions of 61^1 and 61^2 *Cygni* in the assumed direction at the assumed rate may be expressed by

$$\Delta\sigma_0 + \Delta'\sigma_0$$

as computed for each value of τ, and printed in columns nine and ten of Table XIII. This quantity is additive to the observed distance on each plate to reduce to the mean epoch.

31. By the formula of paragraph 17 may be computed values of K or $\Delta\chi_0$ applicable to the new mean epoch adopted, thus :

$$\Delta\chi_0 = [9.7895]\,\tau\rho$$

where the number in brackets is a logarithm as usual.
We also have, as in paragraph 30,

$$\cot \Delta'\pi_0 = \frac{1}{\tau\rho_0'} \cdot \frac{\sigma - \Delta\sigma_0}{\sin(\chi_0' - z)} - \cot(\lambda_0' - z)$$

and

$$\cot y = \frac{1}{\sigma_0} \cdot \frac{\tau\rho_0}{\sin(\pi_0 - \lambda_0)} - \cot(\pi_0 - \chi_0)$$

---

* Jordan : *Handbuch der Vermessungskunde*, 4te Auflage. Bd. III, § 359, 342.

whence is obtained by substitution of the constants and from the figure:

$$\Delta\pi_0 = 62^\circ 59' 17'' + (y - \Delta\chi_0) \qquad \text{before epoch,}$$
$$= -117^\circ\ 0' 43'' + (y - \Delta\chi_0) \qquad \text{after epoch,}$$

and thus the total change of angle is

$$\Delta\pi_0 + \Delta'\pi_0$$

additive to the observed position-angle. These quantities are printed in columns seven and eight of Table XIII.

When these corrections for proper motion have been applied to the preceding columns of Table XIII we get in the next-to-the-last column of the Table the distance and angle of *61*^{2} good for 1873.546 corrected for all known motions of either star, except for difference of parallax if there be any such difference. This oint will be considered in the following *Contribution*, No. 13.

TABLE XII.—PROPER MOTION OF 61^2 *Cygni.*

Authority.	Date of Observation.	Epoch of Catalogue,	No. of Obs.	Position at Epoch of Catalogue.		Reduction to 1875 + Syst. Correction.		Reduced Position.	Wgt.	C.—O.
	t	*T*	*n*			*A′*		*B*		*R*
				RIGHT ASCENSION.						
				20^h+				$21^h\ 1^m+$		
				m	s	m	s	s		s
Br. 2745	1753.8	1755	2	55	57.41	+5	21.767	19.177	0.3	—.031
Pi. xx:476	1806.2	1800	17	57	57.80	+3	21.497	19.297	0.3	—.089
Abo 482	1828.	1830	62	59	18.34	+2	0.805	19.145	4.0	+.089
Pond 946	1830.	1830	16	59	18.73	+2	0.737	19.467	1.0	—.230
Tay. 9785	1835.	1835	5	59	32.24	+1	47.368	19.608	0.4	—.365
12 Yr$_1$ 1887	1839.	1840	30	59	45.14	+1	34.086	19.226	3.0	+.022
12 Yr$_2$ 1887	1845.	1845	40	59	58.61	+1	20.598	19.208	3.0	+.047
6 Yr. 1358	1850.8	1850	45	60	12.11	+1	7.153	19.263	3.0	—.001
Rad$_1$ 5107	1853.0	1845	19	59	58.76	+1	20.550	19.310	3.0	—.046
Yarn. 9477	1854.8	1860	23	60	37.08	+0	42.174	19.254	2.0	+.012
Rad$_2$ 2059	1856.4	1860	11	60	38.93	+0	40.377	19.307	2.0	—.039
7 Yr. 1743	1856.9	1860	48	60	38.95	+0	40.308	19.258	3.0	+.011
Quet. 9276	1861.6	1865	18	60	51.11	+0	28.134	19.244	3.0	+.031
N. 7 Yr. 2394	1864.0	1864	17	60	49.70	+0	29.569	19.269	3.0	+.009
Poulk.	1866.2	1865	27	60	52.448	+0	26.839	19.287	8.0	—.007
9 Yr. 1976	1872.3	1872	13	61	11.185	+0	8.091	19.276	3.0	+.011
Romb. 4784	1877.9	1875	7	61	19.37	+0	0.002	19.372	4.0	—.078
10 Yr. 3532	1883.6	1880	14	61	32.656	—0	13.394	19.262	3.0	+.039
Green. Yearly	1893.7	1893	10	62	7.565	—0	48.294	19.271	2.4	+.042
				m	s					
Results.	1858.58	1875	424	61	19.291				51.4	
				DECLINATION.						
				$37°+$				$38°7′+$		
				′	″	′	″	″		″
Br. 2745	1753.8	1755	1	33	43.9	+34	13.76	57.66	0.2	—0.78
Pi. xx:476	1805.8	1800	13	46	34.0	+21	26.49	60.49	0.3	—2.21
Abo 482	1828.	1830	33	55	4.7	+12	54.11	58.81	4.0	+0.07
Tay. 9785	1835.	1835	9	56	30.47	+11	29.19	59.66	0.5	—0.59
12 Yr$_1$ 1887	1839.	1840	31	57	55.71	+10	3.00	58.71	3.0	+0.47
12 Yr$_2$ 1887	1844.	1845	36	59	22.02	+ 8	36.89	58.91	3.0	+0.40
6 Yr. 1358	1851.2	1850	35	60	48.67	+ 7	10.90	59.57	3.0	—0.06
Rad$_1$ 5107	1853.2	1845	18	59	23.2	+ 8	36.32	59.52	3.0	+0.04
Yarn. 9477	1854.0	1860	113	63	22.6	+ 4	37.25	59.85	3.0	—0.27
7 Yr. 1743	1857.0	1860	44	63	40.53	+ 4	19.02	59.55	3.0	+0.11
Rad$_2$ 2059	1858.8	1860	10	63	41.8	+ 4	18.51	60.31	2.0	—0.60
N. 7 Yr. 2394	1864.2	1864	19	64	49.69	+ 3	9.90	59.59	3.0	+0.27
9 Yr. 1976	1871.9	1872	14	67	8.90	+ 0	51.16	60.06	3.0	.00
Romb. 4784	1877.9	1875	7	68	0.7	+ 0	0.02	60.72	4.0	—0.50
10 Yr. 3532	1883.6	1880	15	69	26.61	— 1	26.54	60.07	3.0	+0.31
Green. Yearly	1893.7	1893	10	73	12.43	— 5	11.81	60.62	2.4	+0.03
Results.	1857.69	1875	408	68′	0.″150				40.4	

Probably an error of 5″ in Quetelet's declination, hence it has been discarded.

TABLE XIII.—POSITION OF 61^2 *Cygni.*

Plate.	Observed Dist.		Corrections for		Corrected Mean. s	Scale Variation r'	Distance at Date of each Plate. $28''.0124(s - r')$	Correction for Proper Motion of		Distance at 1873.546	Parallax *Co-efficient.*
	East.	West.	Refr.	Scale.				61^1 *Cygni*	61^2 *Cygni*		
1	0.6843	0.6716	3	+ 5	0.6788	+1	19.0176	—5.2484	+5.4774	19.2466	—0.767
2	.6900	.6866	3	0	.6886	+2	.2949	—5.2191	+5.4468	.5226	— .745
3	.6968	.6846	3	0	.6910	+1	.3594	—5.2191	+5.4468	.5871	— .745
4	.6918	.6916	3	0	.6920	0	.3846	—1.6956	+1.7739	.4629	— .572
5	.6877	.6865	3	0	.6874	0	.2557	—1.5652	+1.6381	.3286	— .369
6	.6834	.7012	3	— 2	.6924	+1	.3986	—1.5652	+1.6381	.4715	— .369
7	.6968	.6864	3	+ 3	.6922	+1	.3930	—1.5505	+1.6229	.4654	— .341
8	.6934	.6935	3	0	.6937	—1	.4294	+0.7173	—0.7583	.3884	— .715
9	.6852	.6910	3	0	.6883	0	.2809	0.7173	—0.7583	.2399	— .715
10	.6951	.6940	2	0	.6947	0	.4602	+0.7448	—0.7877	.4173	— .670
11	.7023	.7016	2	+ 1	.7023	0	.6731	+0.7546	—0.7981	.6296	— .650
12	.6955	.6951	3	+ 1	.6958	0	.4910	+0.7546	—0.7981	.4475	— .650
13	.6963	.6992	3	+ 1	.6982	0	.5583	+0.7546	—0.7981	.5148	— .650
15	.6966	.6987	3	— 6	.6974	—1	.5330	+1.5946	—1.7030	.4246	+ .550
16	.6839	.7047	4	0	.6947	0	.4602	+ 1.6312	—1.7433	.3481	+ .415
17	.6935	.6958	3	+ 3	.6953	0	.4770	+ 1.6312	—1.7433	.3649	+ .415
18	.6774	.6957	4	+ 3	.6873	0	.2529	+1.6348	—1.7471	.1406	+ .401
19	.6868	.6846	4	0	.6861	0	.2193	+1.6348	—1.7471	.1070	+ .401
20	.6905	.6889	3	+10	.6910	—1	.3538	+1.6348	—1.7471	19.2415	+0.401
					Means		19.3823			19.3868	

TABLE XIII, *Concluded*.—POSITION OF 61² *Cygni*.

Plate.	Observed Position Angle		Zero Correction plus precession, etc	Refrac	Corrected Mean Angle at Date of each Plate. *P*	Correction for Proper Motion of		Angle at 1873 546	Parallax *Coefficient.*
	East.	West				61¹ *Cygni*	61² *Cygni*		
	° ′ ″	° ′ ″	′ ″	″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
1	203 25 46	203 43 17	12 2	—16	113 46 30	18 31 4	—17 53 47	114 23 47	+6354
2	204 6 26	203 7 26	13 28	—14	51 10	+18 27 0	—17 49 51	28 19	+6732
3	203 20 11	203 31 18	13 34	—20	39 5	+18 27 0	—17 49 51	16 14	+6732
4	203 44 56	203 47 23	12 39	—18	57 56	+ 7 58 50	— 7 41 37	12 9	+8536
5	203 30 8	204 48 33	11 38	—17	114 18 4	+ 7 28 2	— 7 14 49	31 17	+9464
6	204 45 51	204 36 21	11 38	—39	49 52	+ 7 28 2	— 7 14 49	63 5	+9464
7	203 30 28	204 1 21	12 52	—26	1 42	+ 7 24 31	— 7 11 24	14 49	+9533
8	204 15 3	204 9 3	13 3	—20	24 32	— 4 42 11	+ 4 35 26	17 47	+7149
9	205 21 46	203 56 36	14 30	—33	52 38	— 4 42 11	+ 4 35 26	45 53	+7149
10	204 41 33	205 2 20	13 7	— 8	115 4 34	— 4 54 37	+ 4 46 55	56 52	+7689
11	204 3 57	205 29 54	14 13	— 6	0 32	— 4 59 5	+ 4 51 16	52 43	+7889
12	204 49 18	204 22 36	15 35	— 11	114 51 32	— 4 59 5	+ 4 51 16	43 43	+7889
13	204 34 43	203 57 12	13 8	—19	29 11	— 4 59 5	+ 4 51 16	21 22	+7889
15	204 54 37	205 7 44	12 13	— 4	115 13 0	—13 8 31	+12 49 0	53 29	—9045
16	204 58 47	204 47 40	10 58	— 1	3 42	—13 37 52	+13 17 42	43 32	—9677
17	206 5 42	205 55 25	11 10	— 2	116 9 37	—13 37 52	+13 17 42	109 27	—9677
18	204 39 30	204 36 40	11 3	— 2	114 48 17	—13 40 49	+13 20 34	28 2	—9715
19	204 55 18	204 58 48	11 22	— 3	115 8 20	—13 40 49	+13 20 34	48 5	—9715
20	205 11 40	205 39 0	12 38	— 2	38 10	—13 40 49	+13 20 34	114 77 55	—9715
			Means		114 41 30			114 41 30	

IV.—*The Parallax of 61^1 Cygni, deduced from the Rutherfurd Photographic Measures.*

BY HERMAN S. DAVIS.

Read May 3d, 1897.

32. For the purpose of determining the parallax of 61^1 *Cygni* the measures of both distance and position-angle have been used as recorded in the preceding catalogue of sixty-five stars. The method adopted for getting the parallax from the measures of distance is the same as has been used in previous investigations at this Observatory.* Briefly stated this consists of correcting the observed distances for refraction, aberration, errors of the scale. proper motion of 61^1 *Cygni*, etc. These distances so corrected may be obtained from Table V by taking the sums of the quantities in columns eight, nine and ten. These sums are printed in columns two and three of Table XVI.

33. Then particular pairs of comparison stars were so chosen that their components should be as nearly as possible equally distant from 61^1 *Cygni* and differing 180° in position-angle. Table XIV contains a catalogue of these stars with memorandum of some other observers who have used the same stars for determining the parallax of 61 *Cygni*.

In the equations of condition of Table XVII have been introduced an unknown y varying with the time, as a correction of the assumed proper motion; and another unknown x, as the correction of the assumed mean of the distances. The coefficients of the parallax have been obtained as follows: Using the symbols of paragraph 14, the quantities of column eleven, Table V are

$$S_3 P_3 \ , \ S_4 P_4 .$$

Denoting by primed letters all symbols belonging to the *less distant* of the two comparison stars of each pair, we have as the coefficient of the parallax

$$(S_3 P_3 + S_4 P_4) - (S_3' P_3 + S_4' P_4)$$

when the absolute term of the equations is the *difference* of the distance of the comparison stars from 61^1 *Cygni*, after these differences have been corrected by their proportional part of the variation of distance. This variation is deduced from the deviation of the *sum* of the distances on the various plates from the mean of all the plates. See Table XVI, columns four to seven inclusive.

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* *The Parallax of μ and θ Cassiopeiæ*, by HAROLD JACOBY.
The Parallax of η Cassiopeiæ, by HERMAN S. DAVIS.

Equations of condition thus formed are in Table XVII. At the foot of each page of this table will be found the normal equations, the deduced values of the unknowns, with their probable errors and the probable error of one equation of unit weight.

Eight different stars combined in five pairs were used for the determination of the parallax by measures of distance.

34. Whereas heretofore only measures of distance were used for parallax, in the present research measures of angle have also been used. For it has been recently shown* in the case of eight stars among the *Pleiades* whose average distance is 2160″, ranging from 631″ to 3160″, that the displacement on the arc of a great circle by reason of the probable error of observation is but little larger in measures of angle than of distance. This research on the measures of 61^1 *Cygni* has shown in addition that, for the seven stars whose measurement of position-angle I have used, the probable error for one plate of unit weight is ±0″.149 in angle, whereas for the eight stars used in distance it is ±0″.191. The average distance of these stars is only 1956″, ranging from 1075″ to 2754″. This fully justifies the use of position-angle for parallax determination from the RUTHERFURD photographic plates in the present and in future reductions.

35. In the use of measures of position-angle the seven stars were selected irrespective of distance but as equally distributed in angle as possible.

Several methods of reduction suggested themselves, but the following was adopted. The observed angles were corrected as described in paragraphs 16–21. The "reduced angles," obtained from adding together columns six and seven of Table VI and the "variation" of paragraph 21, are printed in Table XVIII.

If x' and y' be introduced for error of the adopted mean of the angles and of proper motion respectively, and the parallax coefficient

$$S_8 P_3 + S_9 P_4$$

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* *On the Permanence of the Rutherfurd Photographic Plates*, by HAROLD JACOBY. Page 282.

from column eight, Table VI, be used, the equations of condition can be formed as in Table XVIII. The solution of these equations is given at the bottom of each page; where also will be found the probable errors of the unknowns; likewise the probable error of one equation of unit weight expressed as change of position-angle and also as reduced to the arc of a great circle by aid of the

$$\text{“Factor”} = 28''.0124 \cdot \sigma \cdot \sin 1'' = [6.1329]\,\sigma$$

36. The values of parallax given by the measures of distance of the various pairs of stars are collected in the first part of Table XV, with their weights, p, deduced from the least-square solution, and the corresponding probable errors, r_π. As the stars 5 and 6 enter respectively into each of two pairs, the "combining weights" of those pairs, (p), were used in computing the mean of the five determinations. The (r_π) is the probable error of the parallax when (p) is regarded as the weight. Hence

$$\text{Parallax} = +\,0''.3999 \pm 0''.0230.$$

In the second part of Table XV are given the values of parallax deduced from the measures of position-angle, with their probable errors r_π. Hence

$$\text{Parallax} = +\,0''.3326 \pm 0''.0189.$$

When these two values are combined with weights which are the reciprocals of the squares of their respective probable errors there results the

$$\text{Mean relative parallax of } 61^1 \textit{ Cygni} = +\,0''.360 \pm 0''.0146$$

TABLE XIV.—COMPARISON STARS.

Comp. Star.	Approximate position referred to 61^1 *Cygni.*		Durchmusterung.		Remarks.
No.	Distance.	Angle.	Number.	Mag.	
	″	°	°		
64	3362	69.74	38:4372	7.8	
6	2660	230.21	37:4159	7.5	
39	3185	13.29	38:4353	8.4	
5	2163	273.11	38:4325	6.0	Johnson.
53	2126	81.10	38:4362	7.8	
54	2165	78.27	38:4363	9.1	
48	1423	105.89	37:4189	7.9	Johnson [Pritchard]· Wilsing.
14	971	296.79	38:4336	8.8	[Pritchard].
37	1337	149.62	37:4180	7.7	[Pritchard].
27	1075	177.26	37:4175	9.0	Johnson· [Pritchard].
48	1423	105.89	37:4189	7.9	
43	1825	143.85	37:4185	9.0	
32	2156	172.68	37:4178	7.5	
23	2501	356.08	38:4341	8.2	
13	2754	341.41	38:4335	9.0	

TABLE XV.—RESULTS.

FROM MEASURES OF DISTANCE.

Comp. Stars.	Relative Parallax of 61^1 *Cygni*	Weights. p	(p)	Probable Error. r_1	r_π	(r_π)	Relative Weights. $\frac{1}{(r_\pi)^2}$
	″				″	″	
64- 6	+0.5211	26.2675	17.5117	±0.1641	±0.0373	±0.0457	479.3
39- 6	+0.4497	19.8822	13.2548	.2562	.0429	.0525	362.7
5-53	+0.3733	22.8220	15.2147	± .2020	±0.0400	±0.0490	416.3
54- 5	+0.2431	21.8784	14.5856	.1576	.0409	.0500	399.2
48-14	+0.3888	8.4314	8.4314	± .1840	±0.0658	±0.0658	230.7
Results	+ **0″.3999**		68.9982	±0″.1912	± **0″.0230**		**1888.2**

FROM MEASURES OF POSITION-ANGLE.

Comp. Stars.	Relative Parallax of 61^1 *Cygni*	Weights. p	σ^2	Probable Error. (r_1)	r_1	r_π	Relative Weight. $\frac{1}{r_\pi^2}$
	″			″	″	″	
37	+0.3028	196 129.40	2278.	±15.70	±0.1018	±0.0354	796.9
27	+0.3779	157 834.62	1471.	29.27	.1525	.0395	641.2
48	+0.2794	110 142.84	2580.	25.49	.1758	.0473	447.5
43	+0.3299	79 259.74	4245.	18.52	.1638	.0557	322.0
32	+0.3442	63 960.30	5921.	12.37	.1293	.0620	259.9
23	+0.3334	44 572.46	7968.	12.33	1496	.0743	181.0
13	+0.4401	36 689.52	9667.	±12.32	±0.1646	±0.0819	149.0
Results	+ **0.3326**	688 588.88			±0″.1488	± **0″.0189**	**2797.5**

TABLE XVI.—OBSERVATIONAL DATA.

COMPARISON STARS 64 AND 6.

Plate No.	Corrected Distance.		Sum of Distances	Mean *minus* Sum	Difference of Distances	Scale Corr.	Corrected Difference
	Star 64	Star 6					
1	120.0484	94.9562	215.0046	—.0152	25.0922	—.0018	25 0904
2	.0593	.9648	.0241	—.0347	.0945	— 0041	.0904
3	.0361	.9600	214.9961	—.0067	.0761	—.0008	0753
4	.0406	.9519	.9925	—.0031	.0887	—.0004	.0883
5	.0495	.9559	215.0054	— 0160	.0936	— 0019	.0917
6	.0321	.9487	214.9808	+.0086	.0834	+.0010	.0844
7	.0632	.9609	215.0241	—.0347	.1023	—.0041	.0982
8							
9	.0305	.9480	214 9785	+.0109	.0825	+.0013	.0838
10	.0351	.9526	.9877	+.0017	.0825	+.0002	.0827
11	.0430	.9487	.9917	—.0023	.0943	—.0003	.0940
12	.0439	.9499	.9938	—.0044	.0940	—.0005	.0935
13	.0425	.9357	9782	+.0112	.1068	+.0013	.1081
15	119.9999	.9668	.9667	+.0227	.0331	+.0027	.0358
16							
17	.9914	.9781	.9695	+.0199	.0133	+.0023	.0156
18							
19	.9998	.9805	.9803	+.0091	.0193	+.0011	.0204
20	.9832	.9701	.9533	+.0361	.0131	+.0042	.0173

Adopted mean, 214.9894 **Assumed value,** 25.0730

TABLE XVII.—PARALLAX EQUATIONS.

COMPARISON STARS 64 AND 6.

Plate.					Residuals Scale.	Residuals Arc.
1	$1.00x$	$-1.14y$	-1.84Π	$+1.74=0$	$+0.46$	$+0''.13$
2	1.00	−1.13	−1.87	+1.74 = 0	+0.39	+ .11
3	1.00	−1.13	−1.87	+0.23 = 0	−1.12	− .31
4	1.00	−0.08	−1.94	+1.53 = 0	−0.23	− .06
5	1.00	−0.04	−1.85	+1.87 = 0	+0.27	+ .08
6	1.00	−0.04	−1.85	+1.14 = 0	−0.46	− .13
7	1.00	−0.04	−1.83	+2.52 = 0	+0.96	+ .27
9	1.00	+0.88	−1.90	+1.08 = 0	−0.86	− .24
10	1.00	+0.89	−1.93	+0.97 = 0	−1.03	− .29
11	1.00	+0.90	−1.93	+2.10 = 0	+0.10	+ .03
12	1.00	+0.90	−1.93	+2.05 = 0	+0.05	+ .01
13	1.00	+0.90	−1.93	+3.51 = 0	+1.51	+ .42
15	1.00	+1.42	+1.99	−3.72 = 0	+1.42	+ .40
17	1.00	+1.45	+1.91	−5.74 = 0	−0.69	− .19
19	1.00	+1.45	+1.93	−5.26 = 0	−0.23	− .06
20	1.00	+1.45	+1.93	−5.57 = 0	−0.54	− .15
					$[vv]=9.81$	

Normal Equations.

$$
\begin{aligned}
+16.0000x+6.6400y-14.8800\Pi+0.1900&=0\\
+16.1850+9.3353-25.1545&=0\\
+58.0200-78.1820&=0
\end{aligned}
$$

Solution.

In units of 2d dec. place of scale.	In Arc.
$\Pi=+1.8602\pm0.1143$	$\Pi=+0''.5211\pm0''.0320$
$y=-0.2695\pm0.2073$	$y=-0''.0755\pm0''.0581$
$x=+1.8299\pm0.2276$	$x=+0''.5126\pm0''.0638$

	Scale.	Arc.
Probable error of one equation	± 0″.5859	= ± 0″.1641

TABLE XVI.—OBSERVATIONAL DATA.

COMPARISON STARS 39 AND 6.

Plate No.	Corrected Distance.		Sum of Distances	Mean *minus* Sum	Difference of Distances	Scale Corr.	Corrected Difference
	Star 39	Star 6					
1	113.7446	94.9562	208.7008	—.0261	18.7884	—.0023	18.7861
2	.7430	.9648	.7078	—.0331	.7782	—.0030	.7752
3	.7364	.9600	.6964	—.0217	.7764	—.0020	.7744
4							
5							
6	.7575	.9487	.7062	—.0315	.8088	—.0028	.8060
7							
8							
9	.7218	.9480	.6698	+.0049	.7738	+.0004	.7742
10	.7204	.9526	.6730	+.0017	.7678	+.0002	.7680
11	.7166	.9487	.6653	+.0094	.7679	+.0008	.7687
12							
13	.7230	.9357	.6587	+.0160	.7873	+.0014	.7887
15	.7000	.9668	.6668	+.0079	.7332	+.0007	.7339
16	.6976	.9552	.6528	+.0219	.7424	+.0020	.7444
17	.6843	.9781	.6624	+.0123	.7062	+.0011	.7073
18	.6968	.9650	.6618	+.0129	.7318	+.0012	.7330
19	.6970	.9805	.6775	—.0028	.7165	—.0003	.7162
20	.6766	.9701	.6467	+.0280	.7065	+.0025	.7090

Adopted mean, 208.6747

Assumed value, 18.7560

TABLE XVII.—PARALLAX EQUATIONS.

COMPARISON STARS 39 AND 6

Plate.					Residuals Scale.	Arc.
1	1.00x	−1.14y	−1.30Π	+3.01 = 0	+0.52	+″.15
2	1.00	−1.13	−1.37	+1.92 = 0	−0.68	− .19
3	1.00	−1.13	−1.37	+1.84 = 0	−0.76	− .21
6	1.00	−0.04	−1.76	+5.00 = 0	+2.10	+ .59
9	1.00	+0.88	−1.43	+1.82 = 0	−0.29	− .08
10	1.00	+0.89	−1.52	+1.20 = 0	−1.05	− .29
11	1.00	+0 90	−1.55	+1 27 0	−1.03	− .29
13	1.00	+0.90	−1.55	+3.27 = 0	+0.97	+ .27
15	1.00	+1.42	+1.73	−2.21 = 0	+0.92	+ .26
16	1.00	+1.45	+1.81	−1.16 = 0	+2.09	+ .59
17	1.00	+1.45	+1.81	−4.87 = 0	−1.61	− .45
18	1.00	+1.45	+1.81	−2.30 = 0	+0.96	+ .27
19	1.00	+1.45	+1.81	−3.98 = 0	−0 72	− .20
20	1.00	+1.45	+1.81	−4.70 = 0	−1.44	− .40

$[vv] = 20.23$

Normal Equations.

$$
\begin{array}{rrrr}
+14.0000x & +\ 8.8000y & -\ 1.0700\Pi & +\ 0.1100 = 0 \\
 & +19.5704 & +14.8265 & -28.9273 = 0 \\
 & & +37.0751 & -63.9392 = 0
\end{array}
$$

Solution.

In units of 2d dec. place of scale.	In Arc.
$\Pi = +1.6054 \pm 0.2051$	$\Pi = +0''.4497 \pm 0''.0575$
$y = +0\ 2941 \pm 0.3330$	$y = +0\ .0821 \pm 0\ .0933$
$x = -0.0694 \pm 0.3291$	$x = -0\ .0194 \pm 0\ .0922$

	Scale.		Arc
Probable error of one equation =	±0.9145	=	±0″.2562

TABLE XVI.—OBSERVATIONAL DATA.

COMPARISON STARS 5 AND 53.

Plate No.	Corrected Distance.		Sum of Distances	Mean *minus* Sum	Difference of Distances	Scale Corr.	Corrected Difference
	Star 5	Star 53					
1	77.2195	75.9023	153.1218	—.0225	1.3172	— 0002	1.3170
2	2144	9034	.1178	—.0185	.3110	—.0002	.3108
3	.2131	.8892	.1023	—.0030	.3239	— 0000	3239
4							
5							
6	.2135	.8975	.1110	—.0117	.3160	—.0001	.3159
7	.2180	.9198	.1378	—.0385	.2982	— 0003	.2979
8							
9	.2093	.8921	1014	—.0021	.3172	— 0000	.3172
10	.2058	.8913	.0971	+.0022	.3145	+ 0000	3145
11	.2092	.8894	.0986	+.0007	.3198	+.0000	3198
12	.2103	.8845	.0948	+.0045	.3258	+ 0000	.3258
13	.2093	.8958	.1051	—.0058	.3135	—.0001	.3134
15	.2244	.8536	.0780	+.0213	3708	+ 0002	.3710
16	.2169	.8650	.0819	+.0174	.3519	+.0002	3521
17	.2201	.8707	.0908	+.0085	.3494	+.0001	.3495
18	.2254	.8513	.0767	+.0226	.3741	+.0002	3743
19	.2317	.8559	.0876	+ 0117	3758	+.0001	.3759
20	.2199	.8646	.0845	+.0148	.3553	+.0001	3554

Adopted mean, 153.0993 Assumed value, 1 3330

TABLE XVII.—PARALLAX EQUATIONS.

COMPARISON STARS 5 AND 53.

					Residuals.	
Plate.					Scale.	Arc.
1	$1.00x$	$-1.14y$	$+1.90\Pi$	$-1.60 = 0$	$+0.41$	$+0''.11$
2	1.00	-1.13	$+1.90$	$-2.22 = 0$	-0.21	$-\ .06$
3	1.00	-1.13	$+1.90$	$-0.91 = 0$	$+1.10$	$+\ .31$
6	1.00	-0.04	$+1.47$	$-1.71 = 0$	-0.41	$-\ .11$
7	1.00	-0.04	$+1.42$	$-3.51 = 0$	-2.28	$-\ .64$
9	1.00	$+0.88$	$+1.88$	$-1.58 = 0$	$+0.16$	$+\ .04$
10	1.00	$+0.89$	$+1.85$	$-1.85 = 0$	-0.15	$-\ .04$
11	1.00	$+0.90$	$+1.83$	$-1.32 = 0$	$+0.35$	$+\ .10$
12	1.00	$+0.90$	$+1.83$	$-0.72 = 0$	$+0.95$	$+\ .27$
13	1.00	$+0.90$	$+1.83$	$-1.96 = 0$	-0.29	$-\ .08$
15	1.00	$+1.42$	-1.75	$+3.80 = 0$	$+0.64$	$+\ .18$
16	1.00	$+1.45$	-1.57	$+1.91 = 0$	-1.02	$-\ .29$
17	1.00	$+1.45$	-1.57	$+1.65 = 0$	-1.28	$-\ .36$
18	1.00	$+1.45$	-1.55	$+4.13 = 0$	$+1.22$	$+\ .34$
19	1.00	$+1.45$	-1.55	$+4.29 = 0$	$+1.38$	$+\ .39$
20	1.00	$+1.45$	-1.55	$+2.24 = 0$	-0.67	$-\ .19$
				$[vv]$	14.87	

Normal Equations.

$$
\begin{aligned}
+16.0000x + 9.6600y + 8.2700\Pi + 0.6400 &= 0\\
+20.3820y - 12.1142\Pi + 24.9478 &= 0\\
+47.2107\Pi - 58.9600 &= 0
\end{aligned}
$$

Solution.

In units of 2d dec. place of scale.	In Arc
$\Pi = +1.3326 \pm 0.1510$	$\Pi = +0''.3733 \pm 0''.0423$
$y = -0.1213 \pm 0.2593$	$y = -0''.0340 \pm 0''.0726$
$x = -0.6556 \pm 0.2826$	$x = -0''.1836 \pm 0''.0792$

Probable error of one equation $= \pm 0.7211$ (Scale) $= \pm 0''.2020$ (Arc)

TABLE XVI.—OBSERVATIONAL DATA.

COMPANION STARS 54 AND 5.

Plate No.	Corrected Distance		Sum of Distances	Mean *minus* Sum	Difference of Distances	Scale Corr.	Corrected Difference
	Star 54	Star 5					
1	77.3081	77.2195	154.5276	—.0383	0.0886	0	0.0886
2	.3106	.2144	.5250	—.0357	.0962	0	.0962
3	.2969	.2131	.5100	—.0207	.0838	0	.0838
4							
5							
6							
7							
8							
9	.2808	.2093	.4901	—.0008	.0715	0	.0715
10	.2803	.2058	.4861	+.0032	.0745	0	.0745
11	.2740	.2092	.4832	+.0061	.0648	0	.0648
12	.2661	.2103	.4764	+.0129	.0558	0	.0558
13	.2799	.2093	.4892	+.0001	.0706	0	.0706
15	.2449	.2244	.4693	+.0200	.0205	0	.0205
16	.2605	.2169	.4774	+.0119	.0436	0	.0436
17	.2620	.2201	.4821	+.0072	.0419	0	.0419
18	.2507	.2254	.4761	+.0132	.0253	0	.0253
19							
20	.2474	.2199	.4673	+.0220	.0275	0	0.0275

Adopted mean, 154.4893

Assumed value, 0.0590

TABLE XVII.—PARALLAX EQUATIONS.

COMPARISON STARS 54 AND 5.

Plate.					Residuals. Scale.	Residuals. Arc.
1	$1.00x$	$-1.14y$	-1.91Π	$+2.96=0$	-0.10	$-0''.03$
2	1.00	−1.13	−1.90	$+3.72=0$	+0.68	+ .19
3	1.00	−1.13	−1.90	$+2.48=0$	−0.56	− .16
9	1.00	+0.88	−1.89	$+1.25=0$	+0.34	+ .10
10	1.00	+0.89	−1.86	$+1.55=0$	+0.68	+ .19
11	1.00	+0.90	−1.84	$+0.58=0$	−0.27	− .08
12	1.00	+0.90	−1.84	$-0.32=0$	−1.17	− .33
13	1.00	+0.90	−1.84	$+1.16=0$	+0.31	+ .09
15	1.00	+1.42	+1.77	$-3.85=0$	−1.01	− .28
16	1.00	+1.45	+1.59	$-1.54=0$	+1.17	+ .33
17	1.00	+1.45	+1.59	$-1.71=0$	+1.00	+ .28
18	1.00	+1.45	+1.57	$-3.37=0$	−0.68	− .19
20	1.00	+1.45	+1.57	$-3.15=0$	−0.46	− .13
					$[vv]=6.96$	

Normal Equations.

$$
\begin{array}{rrrrl}
+13.0000x & +\ 8.2900y & -\ 6.8900\Pi & -\ 0.2400 & =0 \\
 & +18.2763 & +\ 9.8622 & -26.2564 & =0 \\
 & & +41.1755 & -47.5103 & =0
\end{array}
$$

Solution.

In units of 2d dec. place of scale.	In Arc
$\Pi=+0.8680\pm0.1203$	$\Pi=+0''.2431\pm0''.0337$
$y=+1.0570\pm0.2044$	$y=+0\ .2961\pm0\ .0573$
$x=-0.1955\pm0.2369$	$x=-0\ .0548\pm0\ .0664$

Probable error of one equation = (Scale) ±0.5626 = (Arc) $\pm0''.1576$.

TABLE XVI.—OBSERVATIONAL DATA.

COMPARISON STARS 48 AND 14.

Plate No.	Corrected Distance		Sum of Distances	Mean *minus* Sum	Difference of Distances	Scale Corr.	Corrected Difference
	Star 48	Star 14					
1							
2	50.8127	34.6771	85.4898	—.0210	16.1356	—.0039	16.1317
3	.8164	.6853	.5017	—.0329	.1311	—.0062	.1249
4							
5							
6							
7							
8							
9							
10	.7984	.6690	.4674	+.0014	1294	+.0003	.1297
11	.7972	.6765	.4737	—.0049	.1207	—.0009	.1198
12	.7955	.6742	.4697	—.0009	.1213	—.0002	.1211
13	.7971	.6601	.4572	+.0116	.1370	+.0022	.1392
15	.7785	.6805	.4590	+.0098	.0980	+.0018	.0998
16	.7762	.6744	.4506	+.0182	.1018	+.0034	.1052
17							
18	.7742	.6928	.4670	+.0018	.0814	+.0003	.0817
19	.7680	.6859	.4539	+.0149	.0821	+.0028	.0849
20	.7829	6834	.4663	+.0025	.0995	+.0005	.1000

Adopted mean, 85.4688 Assumed value, 16 1130

TABLE XVII.—PARALLAX EQUATIONS.

COMPARISON STARS 48 AND 14.

Plate.					Residuals.	
					Scale.	Arc.
2	$1.00x$	$-1.13y$	-1.55Π	$+1.87=0$	$+0.32$	$+0''.09$
3	1.00	-1.13	-1.55	$+1.19=0$	-0.36	$-\ .10$
10	1.00	$+0.89$	-1.42	$+1.67=0$	$+0.23$	$+\ .06$
11	1.00	$+0.90$	-1.38	$+0.68=0$	-0.71	$-\ .20$
12	1.00	$+0.90$	-1.38	$+0.81=0$	-0.58	$-\ .16$
13	1.00	$+0.90$	-1.38	$+2.62=0$	$+1.23$	$+\ .34$
15	1.00	$+1.42$	$+1.19$	$-1.32=0$	$+0.84$	$+\ .24$
16	1.00	$+1.45$	$+0.93$	$-0.78=0$	$+1.02$	$+\ .29$
18	1.00	$+1.45$	$+0.90$	$-3.13=0$	-1.37	$-\ .38$
19	1.00	$+1.45$	$+0.90$	$-2.81=0$	-1.05	$-\ .30$
20	1.00	$+1.45$	$+0.90$	$-1.30=0$	$+0.46$	$+\ .13$
					$[vv]=7.58$	

Normal Equations.

$$+11.0000x + 8.5500y - 3.8400\Pi - 0.5000 = 0$$
$$+16.2023 + 5.4665 - 11.7759 = 0$$
$$+17.2456 - 21.5984 = 0$$

Solution.

In units of 2d dec. place of scale.	In Arc.
$\Pi = +1.3880 \pm 0.2261$	$\Pi = +0''.3888 \pm 0''.0634$
$y = -0.0359 \pm 0.2918$	$y = -0\ .0101 \pm 0\ .0818$
$x = +0.5579 \pm 0.3485$	$x = +0\ .1563 \pm 0\ .0976$

	Scale	Arc
Probable error of one equation	$\pm 0.6568 =$	$\pm 0''.1840$

TABLE XVIII.—PARALLAX EQUATIONS.

POSITION-ANGLE. STAR 37.

Plate.	Reduced Angle.					Residuals in arc of great circle.
2	149°35′56″	$1.00x'$	$-1.13y'$	$+146.\Pi$	$-54'' = 0$	$-''.11$
3	36 28	1.00	—1.13	+146.	—22 = 0	+ .10
4	35 37	1.00	—0.08	+152.	—73 = 0	— .25
5	36 10	1.00	—0.04	+145.	—40 = 0	— .05
6	36 55	1.00	—0.04	+145.	+ 5 = 0	+ .24
7	36 28	1.00	—0.04	+143.	—22 = 0	+ .07
8	36 53	1.00	+0.88	+148.	+ 3 = 0	+ .21
9	36 28	1.00	+0.88	+148.	—22 = 0	+ .05
10	36 19	1.00	+0.89	+151.	—31 = 0	— .00
11	36 22	1.00	+0.90	+151.	—28 = 0	+ .02
12	36 3	1.00	+0.90	+151.	—47 = 0	— .10
13	35 52	1.00	+0.90	+151.	—58 = 0	— .18
15	38 5	1 00	+1.42	—156.	+75 = 0	+ .07
16	37 38	1.00	+1.45	—152.	+48 = 0	— .10
17	38 18	1.00	+1.45	—152.	+88 = 0	+ .16
18	37 16	1.00	+1.45	—151.	+26 = 0	— .24
19	37 58	1.00	+1.45	—151.	+68 = 0	+ .03
20	38 2	1.00	+1.45	—151.	+72 = 0	+ .06

149 36 50 = Adopted Mean.

Normal Equations.

$$+18.00x' + 11.56y' + 864.00\Pi - 12.00 = 0$$
$$+19.86 - 876.04 + 474.39 = 0$$
$$+402194.00 - 115427.00 = 0$$

Solution.

$\Pi = +\ 0''.3028 \pm 0''.0355$ $[vv] = 8127.$

$y' = -\ 3\ .9189 \pm 6\ .039$ $\sigma = 1336''.94$

$x' = -\ 11\ .3531 \pm 6\ .368$ Factor = .00648

In Angle. Arc of great circle.

Probable error of one equation = ± 15″.70 = ± 0″.1018

TABLE XVIII.—PARALLAX EQUATIONS.

POSITION-ANGLE. STAR 27.

Plate.	Reduced Angle					Residuals in arc of great circle.
2	177°14′ 9″	$1.00x'$	$-1.13y'$	$+183.H$	$-59.'' = 0$	$+''.03$
3	13 57	1.00	-1.13	$+183.$	$-71. = 0$	$-.03$
10	14 59	1.00	$+0.89$	$+178.$	$-9 = 0$	$+.21$
11	15 3	1.00	$+0.90$	$+176.$	$-5. = 0$	$+.23$
12	14 10	1.00	$+0.90$	$+176.$	$-58. = 0$	$-.05$
13	13 4	1.00	$+0.90$	$+176.$	$-124. = 0$	$-.39$
15	16 11	1.00	$+1.42$	$-169.$	$+63. = 0$	$-.12$
16	16 11	1.00	$+1.45$	$-151.$	$+63. = 0$	$-.08$
18	17 20	1.00	$+1.45$	$-149.$	$+132. = 0$	$+.28$
20	16 14	1.00	$+1.45$	$-149.$	$+66. = 0$	$-.07$

177 15 8.0 = **Adopted Mean.**

Normal Equations.

$$+10.00x' + 7.10y' + 454.00H - 2.00 = 0$$
$$+14.10 - 670.99 + 438.50 = 0$$
$$+287354.00 - 107966.00 = 0$$

Solution.

$H = +0''.3797 \pm 0''.0737$ $[vv] = 13187.$

$y' = -7.1257 \pm 12.65$ $\sigma = 1074''.60$

$x' = -11.8966 \pm 14.69$ **Factor** = .00521

In Angle. Arc of great circle.

Probable error of one equation = ± 29″.27 = ± 0″.1525

TABLE XVIII.—PARALLAX EQUATIONS.

POSITION-ANGLE. STAR 48.

Plate.	Reduced Angle.					Residuals in arc of great circle.
1	105°52′58″	1.00x'	—1.14y'	+ 68.Π	— 3″ = .0	+″.03
2	52 0	1.00	—1 13	+ 74.	—61 = .0	— .35
3	53 23	1.00	—1.13	+ 74.	+22 = .0	+ .22
4	51 32	1.00	—0.08	+102.	—89 = .0	— .48
5	53 43	1.00	—0.04	+119.	+42 = .0	+ .46
6	53 9	1.00	—0.04	+119.	+ 8 = .0	+ .22
7	52 48	1.00	—0.04	+121.	—13 = .0	+ .08
8	52 55	1.00	+0.88	+ 80.	— 6 = .0	+ .06
9	53 3	1.00	+0.88	+ 80.	+ 2 = .0	+ .12
10	52 19	1.00	+0.89	+ 89.	—42 = .0	— .16
11	52 42	1.00	+0 90	+ 92.	—19 = .0	— .00
12	52 36	1 00	+0.90	+ 92.	—25 = .0	— .04
13	52 8	1 00	+0.90	+ 92.	—53 = 0	— .24
15	53 38	1 00	+1.42	—110.	+37 = .0	+ .00
16	54 4	1.00	+1.45	—121.	+63 = .0	+ .16
17	54 12	1.00	+1.45	—121.	+71 = .0	+ .22
18	52 32	1.00	+1.45	—122.	—29 = .0	— .47
19	53 55	1.00	+1 45	—122.	+54 = .0	+ .10
20	53 51	1.00	+1.45	—122.	+50 = .0	+ .07

105 53 1 0 = **Adopted Mean.**

Normal Equations.

$$+19.00x' + 10.42y' + 484.00\Pi + 9.00 = 0$$

$$+21.16 \qquad - 836.67 \qquad + 280.52 = 0$$

$$+201090.00 \qquad - 50207.00 = 0$$

Solution.

$\Pi = +0''.2794 \pm 0''.0766$ $\qquad [vv] = 22847.$

$y' = +2\ \ .0965 \pm 8\ \ .487$ $\qquad \sigma = 1422''.69$

$x' = -8\ \ .7418 \pm 8\ \ .453$ $\qquad$ **Factor** = .00690

In Angle. Arc of great circle.

Probable error of one equation $= \pm 25''.49 = \pm 0''.1758$

TABLE XVIII.—PARALLAX EQUATIONS.

POSITION-ANGLE. STAR 43.

Plate.	Reduced Angle.					Residuals in arc of great circle.
1	143° 50′ 1″	$1.00x'$	$-1.14y'$	$+101\,\Pi$	$-48.'' = 0$	$-''.01$
2	49 42	1.00	-1.13	$+104.$	$-67. = 0$	$-\ .17$
3	50 22	1.00	-1.13	$+104.$	$-27. = 0$	$+\ .18$
10	50 28	1.00	$+0.89$	$+108.$	$-21. = 0$	$+\ .07$
11	50 19	1.00	$+0.90$	$+109.$	$-30. = 0$	$-\ .01$
12	50 16	1.00	$+0.90$	$+109$	$-33. = 0$	$-\ .03$
13	50 17	1.00	$+0.90$	$+109.$	$-32. = 0$	$-\ .02$
15	52 5	1.00	$+1.42$	$-114.$	$+76. = 0$	$+\ .23$
16	51 23	1.00	$+1.45$	-113	$+34 = 0$	$-\ .14$
18	51 43	1.00	$+1.45$	$-112.$	$+54 = 0$	$+\ .04$
19	52 19	1.00	$+1.45$	$-112.$	$+90. = 0$	$+\ .36$
20	50 41	1.00	$+1.45$	$-112.$	$-8. = 0$	$-\ .51$

143 50 49 0 = Adopted Mean.

Normal Equations.

$$+12.00x' + 7.41y' + 181.00\Pi - 12.00 = 0$$

$$+17.50 - 772.69 + 411.17 = 0$$

$$+142537.00 - 54985.00 = 0$$

Solution.

$\Pi = +0''.3299 \pm 0''.0658$ $[vv] = 6788.$

$y' = -9''.8126 \pm 6''.845$ $\sigma = 1824''.90$

$x' = +2''.0830 \pm 7''.280$ Factor $= .00885$

In Angle Arc of great circle.

Probable error of one equation $= 18''.52 = \pm 0''.1638$

TABLE XVIII.—PARALLAX EQUATIONS.

POSITION-ANGLE. STAR 32.

Plate.	Reduced Angle.						Residuals in arc of great circle.
1	172°39′49″	1.00x'	−1.14y'	+93.Π	−30.″	= 0	+0″.08
2	39 51	1.00	−1.13	+93.	−28.	= 0	+ .10
3	39 55	1.00	−1.13	+93.	−24.	= 0	+ .14
4	39 12	1.00	−0.08	+87.	−67.	= 0	− .43
5	39 41	1.00	−0.04	+75.	−38.	= 0	− .18
6	39 51	1.00	−0.04	+75.	−28.	= 0	− .07
7	40 2	1.00	−0.04	+73.	−17.	= 0	+ .03
8	40 11	1.00	+0.88	+92.	− 8.	= 0	+ .10
9	40 1	1.00	+0.88	+92.	−18.	= 0	− .00
10	39 59	1.00	+0.89	+91.	−20.	= 0	− .03
11	40 5	1.00	+0.90	+90.	−14	= 0	+ .03
12	40 18	1.00	+0.90	+90.	− 1	= 0	+ .17
13	40 4	1.00	+0.90	+90.	−15.	= 0	+ .02
15	41 6	1.00	+1.42	−88.	+47.	= 0	− .02
16	40 47	1.00	+1.45	−80	+28.	= 0	− .19
17	41 17	1.00	+1.45	−80.	+58.	= 0	+ .12
18	41 36	1.00	+1.45	−79.	+77.	= 0	+ .32
19	41 19	1.00	+1.45	−79.	+60.	= 0	+ .14
20	40 34	1.00	+1.45	−79.	+15.	= 0	− .33

172°40 19.0 = Adopted Mean.

Normal Equations.

$$
\begin{array}{rrrrl}
+19.00x' & +10.42y' & +\ 649.00\Pi & -\ 23.00 & =0 \\
 & +21.16 & -\ 546.78 & +\ 445.80 & =0 \\
 & & +138871.00 & -49582.00 & =0
\end{array}
$$

Solution.

$\Pi = +0''.3442 \pm 0''.0489$ $[vv] = 5382.$

$y' = -9\ .5621 \pm 4\ .251$ $\sigma = 2155.''55$

$x' = -5\ .3013 \pm 4\ .638$ **Factor** $= .01045$

In Angle. Arc of great circle.

Probable error of one equation $= \pm 12.''37$ $\pm 0.''1293$

TABLE XVIII.—PARALLAX EQUATIONS.

POSITION-ANGLE. STAR 23.

Plate.	Reduced Angle					Residuals in arc of great circle.
1	356°4′49″	1.00x	—1.14y	—79.Π	+ 8.″=0	—0″.08
2	5 12	1.00	—1.13	—79.	+31. =0	+ .20
3	4 49	1.00	—1.13	—79.	+ 8. =0	— .08
4	5 20	1.00	—0.08	—73.	+39. =0	+ .31
5	4 14	1.00	—0.04	—62.	—27. =0	— .45
6	4 40	1.00	—0.04	—62.	— 1. =0	— .13
7	5 7	1.00	—0.04	—60.	+26. =0	+ .20
8	4 50	1.00	+0.88	—78.	+ 9. =0	— .08
9	4 57	1.00	+0.88	—78.	+16. =0	+ .00
10	5 0	1.00	+0.89	—77.	+19. =0	+ .04
11	4 42	1.00	+0.90	—76.	+ 1. =0	— .17
12	4 58	1.00	+0.90	—76.	+17. =0	+ .02
13	5 11	1.00	+0.90	—76.	+30. =0	+ .18
15	4 1	1.00	+1.42	+73.	—40. =0	— .07
16	4 13	1.00	+1.45	+66	—28. =0	+ .05
17	3 59	1.00	+1.45	+66.	—42. =0	— .12
18	4 24	1.00	+1.45	+65.	—17. =0	+ .18
19	3 40	1.00	+1.45	+65.	—61. =0	— .36
20	4 39	1.00	+1.45	+65.	— 2. =0	+ .36
	356 4 41.0	Adopted Mean.				

Normal Equations.

$$\begin{aligned} +19.00x' + 10.42y' &- 555.00\Pi - 14.00 = 0 \\ +21.16 &+ 448.60 - 248.42 = 0 \\ &+97481.00 - 26185.00 = 0 \end{aligned}$$

Solution.

$\Pi = + 0''.3334 \pm 0''.0584$ $[vv] = 5349.$

$y' = - 0\ .6676 \pm 4\ .237$ $\sigma = 2500''.62$

$x' = + 10\ .8423 \pm 4\ .652$ Factor $= .01213$

In Angle. Arc of great circle

Probable error of one equation $= \pm 12''.33 = \pm 0''.1496$

TABLE XVIII.—PARALLAX EQUATIONS.

POSITION-ANGLE. STAR 13.

Plate.	Reduced Angle.						Residuals in arc of great circle.
1	341°25′ 9″	$1.00x$	$-1.14y$	$-73.\Pi$	$+23.''$	$=0$	+0″.11
2	24 30	1.00	—1.13	—73.	—16.	= 0	— .41
3	25 10	1.00	—1.13	—73.	+24.	= 0	+ .12
4	25 40	1.00	—0.08	—72.	+54.	= 0	+ .46
5	25 0	1.00	—0.04	—66.	+14.	= 0	— .04
6	24 55	1.00	—0.04	—66.	+ 9.	= 0	— .11
7	25 6	1.00	—0 04	—65.	+20.	= 0	+ .05
10	25 14	1 00	+0 89	—74.	+28.	= 0	+ .04
11	25 13	1.00	+0.90	—74.	+27.	= 0	+ .02
12	24 59	1.00	+0.90	—74.	+13.	= 0	- .16
13	25 4	1.00	+0.90	—74.	+18.	= 0	— .10
15	23 54	1.00	+1.42	+74.	—52.	= 0	— .20
16	24 13	1.00	+1.45	+69.	—33.	= 0	+ 03
17	24 19	1.00	+1.45	+69.	—27.	= 0	+ .11
18	24 47	1.00	+1.45	+69.	+ 1.	= 0	+ .48
19	23 52	1.00	+1 45	+69.	—54	= 0	— .26
20	23 59	1.00	+1.45	+69.	—47.	= 0	— 16

341 24 46.0 = Adopted Mean.

Normal Equations.

$$+17.00x' + 8.66y' - 365.00\Pi + 2.00 = 0$$
$$+19.62 + 601.51 - 270.02 = 0$$
$$+85293.00 - 30221.00 = 0$$

Solution.

$\Pi = +\ 0''.4401 \pm 0''.0643$ $[vv] = 4672.$

$y' = -\ 4\ .9631 \pm 4\ .591$ $\sigma = 2754''.25$

$x' = +11\ .8592 \pm 4\ .582$ Factor = .01336

In Angle. Arc of great circle

Probable error of one equation = ±12″.32 = ± 0″.1646

The Parallax of 61^2 Cygni.

37. If the coefficients for parallax of 61^2 *Cygni* be computed by the formulæ of paragraphs 14 and 22, we have:

$$S_3 = -0\ 296 \qquad S_8 = +9777.$$
$$S_4 = -0\ 822 \qquad S_9 = -1120.$$

With these, and the values of P_3 and P_4 of paragraph 14, have been obtained the quantities printed in the last column of Table XIII.

38. The measured distances duly corrected for proper motions of both stars are given in the last-but one column of Table XIII. Table XIX contains the equations of condition of the form:

$$x + (t - 1873.546)y + (S_3P_3 + S_4P_4)\,\Pi + \sigma - \sigma_0' = 0$$

from which are derived the values of the unknowns given on the same page.

39. In column nine of Table XIII are given in like manner the corrected position-angles from which the equations of condition of Table XX have been formed after the manner of paragraph 35. They are of the form

$$x' + (t - 1873.546)y' + \sigma \sin 1''\cdot (S_8P_3 + S_9P_4)\,\Pi + \sigma\cdot \sin 1''\cdot (\pi - \pi_0') = 0.$$

The resulting values of the unknowns will be found on the same page.

40. In both these cases, however, we cannot assume the parallax of the reference star to be *nil.* Its value has been shown to be $+0.''360 \pm ''.015$. The mean by weight of the values of parallax of 61^1 with respect to 61^2 obtained from distance and from angle is $+0''.072 \pm ''.028$, wherefore the concluded value of the

Parallax of 61^2 Cygni $= 0''.288 \pm ''.031$

referred indirectly to all the comparison stars given in Table XIV.

TABLE XIX.—PARALLAX EQUATIONS IN DISTANCE.

COMPARISON STAR, *61¹ Cygni.*

Plate					v.
1	1.00x	−1.69y	−0.77Π	−0″.140 = 0	−0″.248
2	1.00	−1.68	−0.74	+ .136 = 0	+ .032
3	1.00	−1.68	−0.74	+ .200 = 0	+ .096
4	1.00	−0.63	−0.57	+ .076 = 0	+ .022
5	1.00	−0.59	−0.37	− .058 = 0	− .085
6	1.00	−0.59	−0.37	+ .085 = 0	+ .058
7	1.00	−0.58	−0.34	+ .078 = 0	+ .055
8	1.00	+0.33	−0.71	+ .001 = 0	− .045
9	1.00	+0.33	−0.71	− .147 = 0	− .193
10	1.00	+0.34	−0.67	+ .030 = 0	− .010
11	1.00	+0.35	−0.65	+ .243 = 0	+ .205
12	1.00	+0.35	−0.65	+ .061 = 0	+ .023
13	1.00	+0.35	−0.65	+ .128 = 0	+ .090
15	1.00	+0.87	+0.55	+ .038 = 0	+ .168
16	1.00	+0.90	+0.42	− .039 = 0	+ .075
17	1.00	+0.90	+0.42	− .022 = 0	+ .092
18	1.00	+0.91	+0.40	− .246 = 0	− .134
19	1.00	+0.91	+0.40	− .280 = 0	− .168
20	1.00	+0.91	+0.40	− .146 = 0	− .033

Normal Equations.

$$+19.000\,000x + 0.010\,000y - 5.350\,000\Pi - 0''.002\,000 = 0$$
$$+15.492\,500 \quad +5.728\,200 \quad -0\;.957\,070 = 0$$
$$+6.262\,300 \quad -0\;.691\,430 = 0$$

Solution.

	Weights.
$x = +0''.0362 \pm 0''.0249$	12.08
$y = +0\;.0272 \pm 0\;.0295$	8.59
$\Pi = +0\;.1282 \pm 0\;.0533$	2.64

Probable error of one equation = ±0″.0865. $[vv] = 0.2634$

TABLE XX.—PARALLAX EQUATIONS IN ANGLE.

COMPARISON STAR, *61¹ Cygni.*

Plate.					v.
1	1.00x'	—1.69y'	+0.597Π	—″.100 = 0	+″.005
2	1.00	—1.68	+ .633	— .074 = 0	+ .033
3	1.00	—1.68	+ .633	— .142 = 0	+ .065
4	1.00	—0.63	+ .802	— .165 = 0	— .103
5	1.00	—0.59	+ .890	— .058 = 0	+ .006
6	1.00	—0.59	+ .890	+ .122 = 0	+ .186
7	1.00	—0.58	+ .896	— .150 = 0	— .086
8	1.00	+0.33	+ .672	— .134 = 0	— .128
9	1.00	+0.33	+ .672	+ .025 = 0	+ .031
10	1.00	+0.34	+ .723	+ .087 = 0	+ .095
11	1.00	+0.35	+ .742	+ .063 = 0	+ .072
12	1.00	+0.35	+ .742	+ .013 = 0	+ .022
13	1.00	+0.35	+ .742	— .113 = 0	— .104
15	1.00	+0.87	— .850	+ .068 = 0	— .031
16	1.00	+0.90	— .910	+ .012 = 0	— .092
17	1.00	+0.90	— .910	+ .383 = 0	+ .279
18	1.00	+0.91	— .913	— .076 = 0	— .181
19	1.00	+0.91	— .913	+ .037 = 0	— .068
20	1.00	+0.91	— .913	+ .205 = 0	+ .100

Normal Equations.

+19.000 000x + 0.010 000y + 4.225 000Π + 0″.003 000 = 0
+15.492 500 — 8.612 500 +1 .231 450 = 0
+12.145 003 —1 .012 807 = 0

Solution.

	Weights.
x' = —0″.0115 ± ″.0200	16.57
y' = —0 .0510 ± .0273 = —0°.151 ± 0°.081	8.87
Π = +0 .0512 ± .0321	6.42

Probable error of one equation = ±0″.0813 [vv] = 0.2326

Incidentally it should be noticed that the assumed annual change in distance of 61^2 from 61^1 was $-0''.128$, the negative sign being used to indicate separation. From the value of y in Table XIX the correction to this is $0''.027$. Thus the RUTHERFURD plates for an interval of only 2.6 years give:

$$\text{Annual increase of distance} = 0''.101 \pm ''.030.$$

In like manner, the assumed increase of position-angle being $0^\circ.370$ and Table XX, giving as a correction a further increase of $0^\circ.151$, there results:

$$\text{Annual increase of angle} = 0^\circ.521 \pm ^\circ.081.$$

But what is of greater significance, there is also a difference of parallax:

$$(61^1 \text{ Cygni} - 61^2 \text{ Cygni}) = +\ 0''.072 \pm ''.028$$

41. This result is so surprising and yet the difference of parallax obtained from angles and from distances is so accordant within the limits of their respective probable errors that I have deemed it advisable to use the very excellent series of measures of the distance of these two stars given by WILSING in *Sitzungsberichten* der Königl. Preuss. Akademie der Wissenschaften*, 1893, Bd. 40, to see what value of the difference of parallax, if any, might be deduced from them.

42. Using AUWERS' values of the right ascension and declination of 61^1 *Cygni* for 1875.0 and his constants of precession we have:

$$\left.\begin{aligned} \alpha &= 21^h\ \ 2^m\ \ 0^s.6 \\ \delta &= 38^\circ\ 12'\ 48''.6 \end{aligned}\right\} \text{for } 1891.0$$

I have taken $p = 114^\circ.692$ for 1873 with an annual variation of $0^\circ.50$ which gives $p = 123^\circ.5$ for 1891.0 quite accurately enough; as an error of a whole degree would, demonstrably, have no sensible effect upon the deduced value of parallax. Therefore:

$$S_3 = [9.9849] \sin 350^\circ.8 = -0.154$$
$$S_4 = [9.9181] \sin 271^\circ.3 = -0.828$$

With these and the values of P_3 and P_4 computed for each date of WILSING's plates† were formed the parallax coefficients

$$S_3P_3 + S_4P_4$$

which are found in the equations of condition of Table XXI.

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*Since given more fully in *Publicationen des Astrophysikalischen Observatoriums zu Potsdam*, Nr. 36, Bd. XI, 1897.

†*Sitzungsberichten*, etc., pages 883–4.

TABLE XXI.—WILSING'S MEASURES.

No.	Date.			Meas. Dist.	Equations of Condition.					Cor-rected Distance.	Distance *minus* Mean. *v*
				″				″		″	″
1	1890	**Oct.**	14.43	21.04	$1.x$	$-0.22y$	$-.82\Pi$	$+.04$	$=0$	20.986	+.004
2			22.43	20.90	1	—0.19	—.79	—.10		20.847	—.135
3		**Nov.**	5.32	20.89	1	—0.16	—.70	—.11	=0	20.842	—.140
4		**Dec.**	17.24	20.95	1	—0.04	—.21	—.05	=0	20.935	—.047
5	1891	**Feb.**	4.29	20.99	1	+0.10	+.48	—.01	=0	21.024	+.042
6		**May**	5.48	21.04	1	+0.34	+.70	+.04	=0	21.073	+.091
7			8.49	20.97	1	+0.35	+.68	—.03		21.001	+.019
8			11.46	21.04	1	+0.36	+.65	+.04		21.071	+.089
9			11.47	20.87	1	+0.36	+.65	—.13		20.901	—.081
10			12.47	20.81	1	+0.36	+.64	—.19		20.837	—.145
11			29.46	20.94	1	+0.40	+.46	—.06		20.947	—.035
12		**June**	5.49	20.91	1	+0.42	+.37	—.09	=0	20.907	—.075
13			16.44	20.85	1	+0.46	+.22	—.15		20.831	—.151
14			17.47	20.81	1	+0.46	+.21	—.19		20.790	—.192
15			17.49	20.76	1	+0.46	+.21	—.24		20.740	—.242
16		**Aug.**	18.40	21.12	1	+0.63	—.60	+.12	=0	21.017	+.035
17			18.41	21.11	1	+0.63	—.60	+.11		21.005	+.023
18			18.43	21.10	1	+0.63	—.60	+.10		20.995	+.013
19			22.42	21.01	1	+0.64	—.64	+.01		20.901	—.081
20			23.44	21.03	1	+0.64	—.65	+.03		20.920	—.062
21			27.41	21.06	1	+0.66	—.69	+.06		20.946	—.036
22			27.42	21.20	1	+0.66	—.69	+.20		21.086	+.104
23			28.45	21.04	1	+0.66	—.69	+.04		20.926	—.056
24			28.46	21.16	1	+0.66	—.69	+.16		21.046	+.064
25			29.38	21.02	1	+0.66	—.70	+.02		20.905	—.077
26			31.37	21.03	1	+0.67	—.72	+.03		20.912	—.070
27			31.39	21.06	1	+0.67	—.72	+.06		20.942	—.040
28		**Sept.**	6.44	21.02	1	+0.69	—.76	+.02	=0	20.896	—.086
29			6.45	21.12	1	+0.69	—.76	+.12		20.996	+.014
30			7.42	21.16	1	+0.69	—.77	+.16		21.036	+.054
31			7.43	21.16	1	+0.69	—.77	+.16		21.036	+.054
32			9.46	20.95	1	+0.69	—.78	—.05		20.825	—.157
33			11.38	20.97	1	+0.69	—.79	—.03		20.844	—.138
34			23.41	21.03	1	+0.72	—.83	+.03		20.898	—.084
35			23.43	21.14	1	+0.72	—.83	+.14		21.008	+.026
36			24.35	20.87	1	+0.72	—.83	—.13		20.738	—.244
37			24.36	21.22	1	+0.72	—.83	+.22		21.088	+.106
38			30.37	20.90	1	+0.75	—.84	—.10		20.764	—.218
39			30.38	21.04	1	+0.75	—.84	+.04		20.904	—.078

Table XXI.—Wilsing's Measures, (*Continued*).

No.	Date.	Meas. Dist.	Equations of Condition.	Corrected Distance.	Distance *minus* Mean. v
		″	″	″	″
40	1891 Oct. 1.37	21.00	1.x+0.75y —.84Π+.00=0	20.864	—.118
41	1.37	21.07	1 +0.75 —.84 +.07	20.934	—.048
42	6.35	21.01	1 +0.77 —.84 +.01	20.873	—.109
43	6.37	21.13	1 +0.77 —.84 +.13	20.993	+.011
44	9.36	21.32	1 +0.78 —.84 +.32	21.182	+.200
45	10.30	21.31	1 +0.78 —.84 +.31	21.172	+.190
46	20.43	21.13	1 +0.80 —.80 +.13	20.994	+.012
47	23.42	21.21	1 +0.81 —.79 +.21	21.074	+.092
48	23.43	21.08	1 +0.81 —.79 +.08	20.944	—.038
49	28.36	21.10	1 +0.82 —.76 +.10	20.965	—.017
50	Oct. 29.32	21.17	1 +0.82 —.75 +.17=0	21.036	+.054
51	Nov. 3.32	21.13	1 +0.84 —.72 +.13	20.998	+.016
52	3.33	21.11	1 +0.84 —.72 +.11	20.978	—.004
53	5.41	21.06	1 +0.84 —.70 +.06	20.930	—.052
54	5.42	21.03	1 +0.84 —.70 +.03	20.900	—.082
55	19.30	21.34	1 +0.88 —.57 +.34	21.217	+.235
56	29.33	21.23	1 +0.91 —.46 +.23	21.115	+.133
57	29.34	21.41	1 +0.91 —.46 +.41	21.295	+.313
58	Dec. 7.23	21.31	1 +0.93 —.35 +.31=0	21.202	+.220
59	11.33	21.25	1 +0.94 —.30 +.25	21.147	+.165
60	12.30	21.18	1 +0.95 —.29 +.18	21.077	+.095
61	12.31	21.26	1 +0.95 —.29 +.26	21.157	+.175
62	17.32	21.13	1 +0.96 —.21 +.13	21.033	+.051
63	17.33	21.07	1 +0.96 —.21 +.07	20.973	—.009
64	25.27	21.32	1 +0.98 —.10 +.32	21.230	+.248
65	25.29	21.11	1 +0.98 —.10 +.11	21.020	+.038
66	25.30	21.09	1 +0.98 —.10 +.09	21.000	+.018
67	1892 Jan. 7.24	21.07	1 +1.02 +.09 +.07=0	20.994	+.012
68	7.26	21.12	1 +1.02 +.09 +.12	21.044	+.062
69	17.29	21.14	1 +1.04 +.24 +.14	21.075	+.093
70	17.30	21.10	1 +1.04 +.24 +.10	21.035	+.053
71	20.25	21.26	1 +1.05 +.28 +.26	21.198	+.216
72	20.27	21.18	1 +1.05 +.28 +.18	21.118	+.136
73	20.28	21.09	1 +1.05 +.28 +.09	21.028	+.046
74	May 8.53	21.08	1 +1.35 +.67 +.08=0	21.028	+.046
75	11.52	21.08	1 +1.36 +.64 +.08	21.024	+.042
76	11.53	21.07	1 +1.36 +.64 +.07	21.014	+.032
77	26.54	21.05	1 +1.40 +.48 +.05	20.977	—.005
78	26.56	21.10	1 +1.40 +.48 +.10	21.027	+.045
79	June 8.49	21.05	1 +1.43 +.32 +.05=0	20.960	—.022
80	8.51	21.07	1 +1.43 +.32 +.07	20.980	—.002
81	17.55	21.17	1 +1.46 +.20 +.17	21.068	+.086
82	28.48	21.16	1 +1.49 +.04 +.16	21.041	+.059

TABLE XXI.—WILSING'S MEASURES, (*Concluded*).

No.	Date.		Meas. Dist.	Equations of Condition.	Corrected Distance.	Distance *minus* Mean. v
83	1892 Dec.	22.36	21″.12	$1.x+1.97y$ —.13Π+″.12=0	20″.947	—″.035
84	1893 Jan.	7.24	21.16	1 +2.02 +.10 +.16	21.003	+.021
85		7.28	21.12	1 +2.02 +.10 +.12	20.963	—.019
86		11.25	21.15	1 +2.03 +.16 +.15	20.997	+.015
87		28.26	21.10	1 +2.08 +.40 +.10	20.964	—.018
88	Feb.	4.26	21.19	1 +2.10 +.49 +.19	21.060	+.078
89	Mar.	23.61	20.98	1 +2.23 +.83 —.02=0	20.869	—.113
90		23.64	21.00	1 +2.23 +.83 .00	20.889	—.093
91		27.62	21.06	1 +2.24 +.84 +.06	20.949	—.033
92	Apr.	6.57	20.95	1 +2.27 +.84 —.05=0	20.837	—.145
93		18.59	21.02	1 +2.30 +.80 +.02	20.900	—.082
94		21.50	21.05	1 +2.31 +.79 +.05	20.929	—.053
95	May	9.55	21.11	1 +2.36 +.66 +.11=0	20.974	—.008
96		10.51	21.11	1 +2.36 +.65 +.11	20.973	—.009
97		15.56	21.10	1 +2.37 +.60 +.10	20.958	—.024
98		23.57	21.09	1 +2.39 +.52 +.09	20.939	—.043
99	June	1.50	21.12	1 +2.41 +.41 +.12=0	20.957	—.025
100		7.49	21.15	1 +2.43 +.34 +.15	20.980	—.002
101		14.49	21.16	1 +2.45 +.24 +.16	20.979	—.003
102		24.44	21.13	1 +2.48 +.10 +.13	20.935	—.047
103	July	4.44	21.22	1 +2.51 —.04 +.22=0	21.009	+.027
104		15.41	21.21	1 +2.54 —.19 +.21	20.984	+.002
105	Aug.	3.41	21.24	1 +2.59 —.44 +.24	20.988	+.006
106	Aug.	4.41	21.23	1 +2.59 —.46 +.23=0	20.977	—.005
107		10.39	21.17	1 +2.61 —.52 +.17	20.909	—.073
108		31.45	21.26	1 +2.67 —.72 +.26	20.977	—.005
109	Sept.	1.49	21.27	1 +2.67 —.73 +.27=0	20.986	+.004
110		15.48	21.22	1 +2.71 —.81 +.22	20.926	—.056

21.00 = Assumed Mean. Σvv = 1″.1032

Mean = 20.982

43. From these equations are obtained the following normal equations and values of the unknowns :

Normal Equations.

$$\begin{array}{rrrrl} +110.0000x & +129.0300y & -19.1300\Pi & +10.3300 & =0 \\ & +215.2083 & -\ 3.9695 & +15.7599 & =0 \\ & & +39.4805 & -\ 3.4429 & =0 \end{array}$$

Solution.

	Weights.
$x = +0''.0180 \pm 0''.0014$	25.49
$y = -0\ .0824 \pm 0\ .0093$	54.42
$\Pi = +0\ .0876 \pm 0\ .0123$	30.81

Probable error of one equation $= \pm 0''.0684$

$[vv] = 1''.1006$

44. It will be noticed that this difference of parallax between 61^1 and 61^2 is in very close agreement with the $+ 0''.072 \pm .''028$ derived from the RUTHERFURD measures. Its probable error and the sum of the squares of the residuals when compared with similar quantities* in WILSING's determination of the parallax of 61^2 *Cygni* would indicate that it has as real an existence in the measures as his own values of the parallax of 61^2 itself; while at the same time bearing testimony to the excellent quality of his measures.

45. Yet this difference of parallax does not preclude the possibility of orbital motion of either 61^1 or 61^2 about a dark companion, as has been suggested by WILSING to account for the systematic irregularity of his measures—a suggestion which the outstanding residuals, after corrections for this difference of parallax have been applied to the measures, would in a degree confirm. And yet it is greatly to be regretted that points numbered 1, 2, 3, and 4 of his curve† are determined by only 4, 2, 2, and 2, exposures on 2, 1, 1, and 1 plates respectively, in contrast with the other points which are determined by the means of from 11 to 40 exposures; and that the most critical portion of the curve (that from January 15th, 1892, to January 13th, 1893) is determined by two points only, from 15 and 11 exposures on only 5 and 4 plates respectively. Moreover, for the reasons stated on page 160 of this paper, the testimony of the PRITCHARD measures, adduced by

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* $[vv] = 2.691$; 2 390 and 1.681 on pages 109, 114 and 120 respectively, *Publicationen*, etc.

† *Sitzungsberichten*, etc., pages 884–5.

JACOBY[*] to corroborate WILSING, should be given no weight at the present time.

On the other hand, it is still an open question whether or not the parallaxes obtained from RUTHERFURD measures may not be affected by systematic errors, the nature and origin as well as existence of which are at present unknown. The case of β *Cygni*[†] as well as Mrs. Davis' deduction of a similarly large parallax from the measures[‡] of "Bradley 3077" give room for this suspicion. It is for this reason that the confirmation of difference of parallax by WILSING's measures is all the more instructive.

46. It should be stated in this connection also, that even if such orbital motion exist, its amplitude is so greatly diminished by this difference of parallax of the two stars as to reduce the sum of the squares of the residuals formed in means for the 22 groups of WILSING's Table on page 885[§] from 0.1708 to 0.1052 or by nearly forty per cent.

In the following Table, are reproduced, in column two, these twenty-two mean residuals[‡] and in column three are given also the mean of the residuals for the same plates from the last column of Table XXI, whereby to facilitate their comparison as to the effect produced by the introduction of the parallax into the equations.

I have also made a second solution of these 110 equations on the assumption that there might be a term whose coëfficient is[||]

$$\tan \zeta \cos (p - q)$$

to account for the unequal effect on the two stars of the atmospheric dispersion. The solution of the equations and the resulting residuals are not contradictory of WILSING's conclusions (from the similarity of the spectra of 61^1 and 61^2) that there is no reason for the introduction of this term. In column four are given, however, the means of the residuals resulting from this solution.

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[*] *Monthly Notices*, Vol. LIV, page 117. See also, *Vierteljahrsschrift*, for 1891, Vol. 26, p. 146.

[†] *Astronomical Journal*, No. 287: On the Probable Large Parallax of β Cygni, by Harold Jacoby.

[‡] Contribution from the Observatory of Columbia University, New York, No. 14.

[§] *Sitzungsberichten*, etc.

[||] *Publicationen des Astrophysikalischen Observatoriums zu Potsdam*, No 36, page 144.

[¶] *Monthly Notices*, Vol. LV, page 123. But see also Vol. LVIII, page 83.

TABLE XXII.—WILSING'S MEASURES.

(See Paragraph 46.)

No. of Point on Curve.	Mean of Residuals.			Weight.		Mean Date.
	Wilsing.	With Parallax.	With Paral. and Atmos. Dispersion.	Plates.	Expos.	
	″	″	″			
1	+.041	—.066	—.073	2	4	1890 Oct. 18
2	—.039	—.140	—.142	1	2	Nov. 5
3	+.001	—.047	—.084	1	2	Dec. 17
4	+.031	+.042	—.041	1	2	1891 Feb. 4
5	—.039	—.010	+.052	6	12	May 13
6	—.179	—.165	—.145	4	8	June 14
7	+.071	—.015	—.003	12	24	Aug. 25
8	+.031	—.063	—.047	12	24	Sept. 17
9	+.111	+.018	+.026	10	19	Oct. 13
10	+.131	+.077	+.066	8	16	Nov. 11
11	+.151	+.111	+.069	9	17	Dec. 17
12	+.091	+.088	+.018	7	14	1892 Jan. 15
13	—.009	+.032	+.043	5	15	May 16
14	+.011	+.030	+.038	4	11	June 15
15	—.009	+.007	—.061	6	40	1893 Jan. 13
16	—.159	—.080	—.043	3	19	Mar. 24
17	—.169	— 093	—.054	3	24	April 15
18	—.089	—.021	—.014	4	34	May 14
19	—.049	—.019	+.004	4	32	June 11
20	+.021	+.012	+.026	3	24	July 18
21	+.011	—.028	—.002	3	25	Aug. 15
22	+.031	—.026	—.022	2	18	Sept. 8

47. Several astronomers have investigated the parallax of these stars by measures with reference to the point mid-way between 61^1 and 61^2; others with reference to either star independently of the other. In Table XXIII are gathered many of the results of such investigations where the stars were individually observed. When the same measures have been reduced in several different ways or by different persons, that result which is regarded as definitive has been printed in heavy type, the lightface type being used in other cases. The numbers in the last column refer to the list of reference books given on pages 159–160.

TABLE XXIII.—VARIOUS VALUES OF PARALLAX OF 61^1 CYGNI.

Method.	Star of Comparison.	Parallax of 61^1 Cygni.	Probable error r	Authority.	Ref. No.
δ	Absolute	+0″.349	±0″.080	Peters	2
$\Delta\delta$	38°4351	.4654	.0497	Ball	8
$\Delta\delta$	38°4351	.400	.055	Ramb. Ball	15
α	Absolute (?)	.50	.094	Belopolsky	10
$\Delta\alpha$		.21	.03	Flint	16
Photography	Ten Stars	.30	.031	Kapteyn	17
		Distance.			
Photography	37°4189	[+0″.4294]	±0″.0162	Pritchard	12
"	38°4336	[.4414]	.0222	Pritchard	12
"	37°4175	[.4448]	.0212	Pritchard	12
"	38°4348	[.4193]	.0182	Pritchard	12
Photography	38°4372—37°4159	.5211	.0373	Davis	13
"	38°4353—37°4159	.4497	.0429	Davis	13
"	38°4325—38°4362	.3733	.0400	Davis	13
"	38°4363—38°4325	2431	.0409	Davis	13
"	37°4189—38°4336	.3888	.0658	Davis	13
Photography	37°4189	.405	.026	Wilsing	14
		Position Angle.			
Photography	37°4180	+0″.3028	±0″.0354	Davis	13
"	37°4175	.3779	.0395	Davis	13
"	37°4189	.2794	.0473	Davis	13
"	37°4185	.3299	.0557	Davis	13
"	37°4178	.3442	.0620	Davis	13
"	38°4341	.3334	.0743	Davis	13
"	38°4335	.4401	.0819	Davis	13

TABLE XXIII.—VARIOUS VALUES OF PARALLAX OF 61^2 CYGNI.

Method.	Star of Comparison.	Parallax of 61^2 Cygni.	Probable error r	Authority.	Ref. No.
$\Delta\delta$, Microm.	38°4351	+0″.4676	±0″.0321	Ball	9
“	38°4345	.2698	.0130	A. Hall	11
“	38°4345	.3217	.0213	A. Hall	11
“	$\Delta\alpha = -63^s.5$ $\Delta\delta = -34''$	.2005	.0246	A. Hall	11
$\Delta\alpha$	Absolute (?)	.55	.091	Belopolsky	10
Photography	Ten Stars.	.36	.034	Kapteyn	17
		Distance			
Micrometer	38°4345	0″.5092	±0″.0355	O. Struve	3
“	“	.5179	.0328	Lamp's Struve	6
Micrometer	38°4345	.4365	.0738	Socoloff's Schweizer	5
“	“	.4885	.0824	Socoloff's Schweizer	5
“	“	.4388	.0654	Lamp's Socoloff's Schweizer	6
“	“	.5220	.0770	Lamp's Socoloff's Schweizer	6
“	“	.4594	.0637	Lamp's Schweizer	6
“	“	.4715	.0684	Lamp's Schweizer	6
Photography	37°4189	[.4250]	.0176	Pritchard	12
“	38°4336	[.4508]	.0191	Pritchard	12
“	37°4175	[.4320]	.0190	Pritchard	12
“	38°4348	[.4303]	.0178	Pritchard	12
Photography	61¹ *Cygni*	.288	.031	Davis	13
Photography	37°4189	.357	.017	Wilsing	14
		Position-Angle.			
Micrometer	38°4345	+0″.5008	±0″.0466	O. Struve	3
“	“	.4913	.0371	Lamp's Struve	6
Micrometer	38°4345	.3761	.0439	Socoloff's Schweizer	5
“	“	.4926	.0546	Socoloff's Schweizer	5
“	“	.3925	.0438	Lamp's Socoloff's Schweizer	6
“	“	.4957	.0512	Lamp's Socoloff's Schweizer	6
“	“	.3818	.0457	Lamp's Schweizer	6
“	“	.4824	.0517	Lamp's Schweizer	6

48. While there is some dependence of one result on another in those instances where the same star of comparison was used, yet, as the measures were made by independent observers and dissimilar methods, and show in themselves no indication of a parallax of the comparison-star, it is not improper to combine all these individual results into means by weights proportional to the reciprocal of the square of the probable error. Thus we have the mean of previous determinations of the

$$\text{Parallax of } 61^1 \text{ Cygni} = 0.''417 + 0''.0216$$

and, in like manner excluding my own determinations:

$$\text{Parallax of } 61^2 \text{ Cygni} = 0''.335 + 0''.0076$$

which give:

$$61^1 - 61^2 = +0.''082 \ \pm 0''.023 \quad [+0''.054 \pm 0''.010]$$

and if the Rutherfurd results be included as given in Table XXIII, this becomes:

$$61^1 - 61^2 = +0''.048 \pm 0''.014 \quad [+0''.035 \pm 0''.009]$$

The numbers placed in the brackets are what these values would have been had Pritchard's results not been discarded.

49. Let us now tabulate these differences of parallax of the two stars under consideration:

Davis' Rutherfurd,—direct measures of distance	+	0″.128	+″.053
Davis' Rutherfurd,—direct measures of angles	+	.051	.032
Adopted Mean =	+	0″.072	± ″.028
Davis' Wilsing,—direct measures of distance	+	.088	.012
Wilsing's $(61^1 - 6) - (61^2 - 6)$*	+	.048	.031
Mean of all determinations† previous to Rutherfurd =	+	.082	.013
Mean of all determinations including Rutherfurd =	+	.048	.014

The magnitude and accordance of these values when considered in connection with their respective probable errors leave little room for doubt as to the reality of the difference of parallax detected by the measures of the Rutherfurd plates, and discarding Pritchard's results in no respect lessens the force of the argument. So that if 61^1 *Cygni* be really a binary system of which

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***Publicationen des Astrophysikalischen Observatoriums zu Potsdam*: Nr. 36. page 148.

†As determined from Table XXIII on pages 155–6, using only the values in bold type.

one member is a dark body* it is nevertheless far removed from the influence of 61^2 *Cygni*, which would account for the as yet unproved† orbital motion of 61^1 and 61^2 around a centre of gravity common to the two. The probabilities in favor of the existence of such orbital motion, if they really have the *same* parallax, are fully as strong as are those against the juxtaposition in line of sight of two stars having so nearly the same large apparent motion, if they are really separated in space by the distance which this *difference* of parallax indicates.

This presents to us therefore one of those cases where the exceedingly strong probability against an event happening is perhaps overruled by its actual occurrence.

The evidence here presented as to a difference of parallax is at any rate of sufficient weight to demand a more extended series of photographic measures of the same degree of precision as WILSING's and extending over more than two years. Perhaps Prof. Wilsing would himself be willing to continue his series of plates. It is also highly desirable to reinforce the evidence of a variable proper motion of 61^1 by independent methods, such as is afforded by the spectroscope, for example.

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* *Publications of the Lick Observatory*, Vol. II, 1894. Page 122. BURNHAM records his inability to see at 1889.463 and 1889.502 a companion to either star, though using the 36-inch telescope with powers up to 1000.

† *Monthly Notices*, Vol. XXXV, page 323. *Ast. Nach.*, Vol. 132, pages 87 and 199. BURNHAM in *The Sideral Messenger*, Vol. X, page 1, and MANN, *ibid.* page 13.

Reference Books.—(See TABLE XXIII.)

(1.) **BESSEL**—Astronomische Nachrichten, No. 365–6, and Vol. XVII.

(2.) **PETERS**—Recherches sur la Parallaxe des Étoiles Fixes. Recueil de Mémoires présentés à l' Académie des Sciences par les Astronomes de Poulkova. Vol. I, page 136.

(3.) **STRUVE**—Nouvelle Détermination de la Parallaxe annuelle des Étoiles *a* Lyræ et 61 Cygni. Memoires de l' Académie Impériale des Sciences de St.-Pétersbourg, VII Série. Vol. I, No. 1, page 44.

(4.) **AUWERS**—Untersuchungen über die Beobachtungen von Bessel und Schlüter am Königsberger Heliometer zur Bestimmung der Parallaxe von 61 Cygni. Abhandlungen der Academie zu Berlin, 1868: page 113.

(5.) **SOCOLOFF**—Parallaxes des Étoiles observées par G. Schweizer. Annales de l' Observatoire de Moscou, Vol. VIII, 2, pages 89–90.

(6.) **LAMP**—Neue Berechnung der Parallaxe von 61 Cygni aus den Beobachtungen von Schweizer in Moskau 1863–1866, Kiel, 1883, pages 52–9.

(7.) **JOHNSON**—Introduction to the Observations with the Heliometer. Part II of Astronomical Observations made at the Radcliffe Observatory in the year 1853. Vol. XIV, page xxxix.

(8.) **BALL**—On a new Determination of the Parallax of the Preceding Star of 61 Cygni by the Method of Differences of Declination. Astronomical Observations and Researches made at Dunsink. Part III, page 27.

(9.) **BALL**—Further Researches on the Parallax of 61 Cygni. Astronomical Observations and Researches made at Dunsink. Part V, page 166.

(10.) **BELOPOLSKY**—Astronomische Nachrichten, No. 2888.

These values of parallax are computed from discordances in right ascension between observations made six months apart on the transit instrument by WAGNER at Poulkova in 1862–1870.

(11.) **HALL**—Observations for Stellar Parallax. Washington Observations for 1883, Appendix II, pages 54 and 67.

(12.) PRITCHARD—Researches in Stellar Parallax by the aid of Photography, from Observations made at the Oxford University Observatory, Oxford, 1889.

In the formation of Table XXIII, giving the various values of the parallax of 61 *Cygni* hitherto published, I have not placed Pritchard's values in bold type, because they cannot be regarded as trustworthy. They have been discarded in taking the means of the determinations for 61^1 and 61^2. I have examined the eight sets of normal equations given in the work on 61 *Cygni* (pages 17–63) and among the eight sets have not found one which is correct in every quantity. The set on page 30 first attracted my attention and so it may be used for illustration. As given there the quantities are:

$$\begin{array}{rcrrr}
-\ 1''.3140 & = & +\ 88\ 0000\ x & -\ 6.7889\ d\mu & -\ 2.5442\ \pi \\
+\ 4\ \ .3827 & = & -\ 6\ 7889 & +\ 8.4762 & +\ 9.7965 \\
+17\ \ .1716 & = & -\ 2.5442 & +\ 9.7965 & +38.7724
\end{array}$$

These should be:

$$\begin{array}{rcrrr}
-\ 1''.2180 & = & +\ 88.0000\ x & -\ 6.7889\ d\mu & -\ 0.9281\ \pi \\
+\ 4\ \ .3853 & = & -\ 6.7889 & +\ 8.4783 & +\ 9\ 7854 \\
+17\ \ .1967 & = & -\ 0.9281 & +\ 9.7854 & +38.7849
\end{array}$$

This criticism applies not only to the normals for 61 *Cygni* but for many of the other stars as well. No attempt has been made to verify all the numbers in each set of normals, nor indeed to extend the test to all sets of normals given in the book, but it can be stated that at least one number is wrong in each of the fourteen sets given on pages 17, 23, 30, 36, 47, 52, 58, 73, 75, 87, 104, 106, 107 and 113.

(13.) DAVIS—Contributions from the Observatory of Columbia University, New York, No. 13.

(14.) WILSING—Untersuchungen uber die Parallaxe und die Eigenbewegung von 61 Cygni nach Photographischen Aufnahmen. Publicationen des Astrophysikalischen Observatoriums zu Potsdam, No. 36, pages 152 and 148.

(15.) RAMBAUT—On the Effects of Atmospheric Dispersion on the Position of a Star. Monthly Notices, Vol. LV, page 123.

(16.) FLINT—Research Work at the Washburn Observatory. The Astrophysical Journal, Vol. VI, page 420.

A preliminary announcement of results now in process of computation.

(17.) KAPTEYN—Bestimmung von 250 Parallaxen. Astronomische Nachrichten, Bd. 145, S. 300.

V.—*The Rutherfurd Photographic Measures of Thirty-four Stars near "Bradley 3077."*

BY HERMAN S. DAVIS.

Read May, 1897.

1. The methods of reduction employed in the formation of this catalogue are the same as have been described in my paper on *Sixty-five Stars near 61 Cygni*, except that no corrections for parallax were applied. The computations have been almost entirely performed by Mrs. Davis, who has also rendered considerable assistance in the computations connected with all my other papers on the *Rutherfurd Measures.*

In this presentation of results the Tables have been given numbers to correspond with the similar tables in the paper on *61 Cygni*, reference to which will make clear any matter not sufficiently intelligible from the captions to the various columns.

2. Nearly the mean date of observation, 1874.0, was selected as the epoch to which the observations were reduced. Thus we have:

$$\Delta p_{73} = -\,8'' + [0.919]\,A + [0.246_n]\,B + [0.167_n]\,C + [9.537]\,D$$
$$\Delta p_{74} = \quad 0 \quad + [0.919]\,A + [0.246_n]\,B + [0.167_n]\,C + [9.537]\,D$$

as the correction for precession, nutation and aberration in position-angle; and, for all years, to correct for aberration in distance:

$$\Delta s = \{[4.058]C + [4.416_n]D\}s$$

3. The logarithms of the Besselian day-numbers, taken from the *American Ephemeris*, are:

Plates.	log *A*.	log *B*.	log *C*.	log *D*.
1, 2, 3,	9.786	0.808_n	1.053	1.213
4, 5, 6,	9.805	0.801_n	0 958	1.253
7, 8,	9.336	0.857_n	0.776_n	1.287_n
9, 10,	9.411	0.854_n	0.418_n	1.306_n
11, 12.	9.417	$0\ 854_n$	0.364_n	1.307_n

4. Argelander's position and proper motion of this star as given in *Mittlere Positionen von 160 Sternen* have been adopted. For 1874.0 they are:

$$\alpha = 23^{h}\,07^{m}\,13^{s}.356 \qquad \mu = +0^{s}.24867$$
$$\delta = 56^{\circ}\,28'\,21''.95 \qquad \mu' = +0''.2685$$

From these are derived:

$$\rho = 2''.07765 = 0^{d}.07416 \qquad \chi = 82^{\circ}\,34'\,29''$$

The values of P_1, P_2, P_5, and K, depending hereon, are in Table VII on page 184; and S_1, S_5, S_6, and S_7, are in Table VIII.

5. For determining the correction for scale-variation, stars numbered 3, 9, 19, 20, 31 and 33 have been used. These are so distributed that

$$\Sigma s_s = 428^{d}.6222, \quad \Sigma \cos p = -0.01, \quad \text{and } \Sigma \sin p = -0.10$$

Therefore the

$$\text{Scale variation} = \frac{\Sigma s_s - (s_3 + s_9 + s_{19} + s_{20} + s_{31} + s_{33})}{\Sigma s_s}\, s.$$

This factor of s will be found on page 184.

6. The correction for orientation variation on page 184 has been deduced in the same manner as described in paragraphs 19–21 of the paper on *61 Cygni*, except that Mrs. Davis has reduced the orientation to the mean of all the plates excluding that numbered six, regarding for very obvious reasons the mean of the remaining eleven as nearer the truth than the mean of the entire twelve. Thus the corrections actually applied reduces the orientation to the mean of the remaining eleven plates. The nine stars whose numbers are 8, 9, 10, 11, 14, 16, 17, 20 and 33 after correction for proper motion have been used as standards. They give:

$$\frac{\Sigma\sigma^2 S_8}{\Sigma\sigma^2} = +6.0 \quad \text{and} \quad \frac{\Sigma\sigma^2 S_9}{\Sigma\sigma^2} = -2.3$$

7. For calculating the difference of right ascension and of declination the following constants have been used:

$$\log P = 0.257799 \qquad \log R = 9.5094_{n} \qquad \log T = 4.5633_{n}$$
$$\log Q = 5.1221 \qquad \log S = 0.0458 \qquad \log U = 9.4870_{n}$$

Also, by paragraph 24 of *Catalogue of Sixty-five Stars near 61 Cygni*.

$$n = \sigma \sin \pi$$
$$m = \sigma \cos \pi$$
$$\alpha' - \alpha = Pn + Qnm + Rn^3 + Snm^2$$
$$\delta' - \delta = m + Tn^2 + Un^2 m$$

TABLE I.—GENERAL DATA.—Observatory of L. M. Rutherfurd, New York.

Lat. = 40° 43′ 48″.5 Long. = $4^h 55^m 56^s.62$ W

Plate.	Date.	Sidereal Time.	Hour Angle.	Barom.	Att. Therm	*Ext. Therm.	Tel. Therm.	Focus.	Zero.	ζ	q	log κ
		h m s	h m s		°	°	°			°	°	
1	1873 Nov. 14	1 54 3	2 46 53	30.132	29	28	30	8.0	58.60	31.09	+102.42	6.4709
2	Nov. 14	2 28 3	3 20 53	30.132	29	28	30	8.0	63.73	35.73	+ 94.30	6.4707
3	Nov. 14	3 4 3	3 56 53	30.132	29	28	30	8.0	59.19	40.70	+ 86.73	6.4704
4	Nov. 22	2 45 33	3 38 23	30.418	36	35	36	7.8	54.68	38.16	+ 90.51	6.4682
5	Nov. 22	3 18 23	4 11 13	30.418	36	35	36	7.8	58.90	42.67	+ 83.92	6.4679
6	Nov. 22	3 50 43	4 43 33	30.418	36	35	36	7.8	40.86	47.08	+ 77.89	6.4676
7	1874 June 1	19 7 7	19 59 54	29.984	60	55	60	7.7	54.11	41.15	— 86.09	6.4437
8	June 1	19 44 23	20 37 10	29.984	60	55	60	7.7	54.73	36.00	— 93.86	6.4440
9	June 12	18 27 27	19 20 14	29.950	71	69	70	7.64	54.15	46.57	— 78.58	6.4305
10	June 12	19 0 17	19 53 4	29.950	71	69	70	7.64	48.89	42.09	— 84.75	6.4312
11	June 13	18 59 43	19 52 30	30.300	59	57	60	7.7	54.21	42.16	— 84.64	6.4466
12	June 13	19 33 33	20 26 20	30.300	59	57	60	7.7	54.35	37.50	— 91.51	6.4469

TABLE II.—CORRECTIONS FOR REFRACTION.

Position Angle, p		$\frac{\sigma-s}{s}\times 10^3$	$\pi-p$	Position Angle, p		$\frac{\sigma-s}{s},\times 10^3$	$\pi-p$
PLATE 1.				PLATE 2.			
			″				″
102°	282°	+.410	0.0	94°	274°	+.456	0.0
112	292	.406	− 3.9	104	284	.451	− 5.5
122	302	.397	− 7.2	114	294	.438	−10.4
132	312	.383	− 9.7	124	304	.417	−13.9
142	322	.365	−11.1	134	314	.392	−15.8
152	332	.345	−11.1	144	324	.365	−15.8
162	342	.328	− 9.7	154	334	.339	−13.9
172	352	.314	− 7.2	164	344	.319	−10.4
182	2	.304	− 3.9	174	354	.306	− 5.5
192	12	.301	0.0	184	4	.301	0.0
202	22	.304	+ 3.9	194	14	.306	+ 5.5
212	32	.314	+ 7.2	204	24	.319	+10.4
222	42	.328	+ 9.7	214	34	.339	+13.9
232	52	.345	+11.1	224	44	.365	+15.8
242	62	.365	+11.1	234	54	.392	+15.8
252	72	.383	+ 9.7	244	64	.417	+13.9
262	82	.397	+ 7.2	254	74	.438	+10.4
272	92	.406	+ 3.9	264	84	.451	+ 5.5
282	102	.410	0.0	274	94	.456	0.0
PLATE 3.				PLATE 4.			
			′				″
87°	267°	+.521	0.0	91°	271°	+.483	0.0
97	277	.515	− 7.8	101	281	.477	− 6.5
107	287	.496	−14.7	111	291	.462	−12.2
117	297	.466	−19.8	121	301	.437	−16.4
127	307	.430	−22.5	131	311	.407	−18.7
137	317	.391	−22.5	141	321	.375	−18.7
147	327	.355	−19.8	151	331	.344	−16.4
157	337	.326	−14.7	161	341	.320	−12.2
167	347	.306	− 7.8	171	351	.305	− 6.5
177	357	.300	0.0	181	1	.299	0.0
187	7	.306	+ 7.8	191	11	.305	+ 6.5
197	17	.326	+14.7	201	21	.320	+12.2
207	27	.355	+19.8	211	31	.344	+16.4
217	37	.391	+22.5	221	41	.375	+18.7
227	47	.430	+22.5	231	51	.407	+18.7
237	57	.466	+19.8	241	61	.437	+16.4
247	67	.496	+14.7	251	71	.462	+12.2
257	77	.515	+ 7.8	261	81	.477	+ 6.5
267	87	.521	0.0	271	91	.483	0.0

TABLE II.—CORRECTIONS FOR REFRACTION. (*Continued.*)

Position Angle, p		$\frac{\sigma-s}{s} \times 10^3$	$\pi-p$	Position Angle, p		$\frac{\sigma-s}{s} \times 10^3$	$\pi-p$
PLATE 5.				PLATE 6.			
84°	264°	+.552	0″.0	78°	258°	+.644	0″.0
94	274	.544	− 8.9	88	268	.634	−12.2
104	284	.523	−16.8	98	278	.603	−22.8
114	294	.489	−22.6	108	288	.557	−30.8
124	304	.448	−25.7	118	298	.502	−35.0
134	314	.403	−25.7	128	308	.441	−35.0
144	324	.361	−22.6	138	318	.385	−30.8
154	334	.328	−16.8	148	328	.339	−22.8
164	344	.307	− 8.9	158	338	.309	−12.2
174	354	.299	0.0	168	348	.299	0.0
184	4	.307	+ 8.9	178	358	.309	+12.2
194	14	.328	+16.8	188	8	.339	+22.8
204	24	.361	+22.6	198	18	.385	+30.8
214	34	.403	+25.7	208	28	.441	+35.0
224	44	.448	+25.7	218	38	.502	+35.0
234	54	.489	+22.6	228	48	.557	+30.8
244	64	.523	+16.8	238	58	.603	+22.8
254	74	.544	+ 8.9	248	68	.634	+12.2
264	84	.552	0.0	258	78	.644	0.0
PLATE 7.				PLATE 8.			
274°	94°	+.498	0″.0	266°	86°	+.432	0″.0
284	104	.491	− 7.6	276	96	.427	− 5.3
294	114	.473	−14.3	286	106	.414	− 9.8
304	124	.444	−19.3	296	116	.394	−13.3
314	134	.409	−21.9	306	126	.370	−15.1
324	144	.372	−21.9	316	136	.344	−15.1
334	154	.336	−19.3	326	146	.320	−13.3
344	164	.308	−14.3	336	156	.300	− 9.8
354	174	.288	− 7.6	346	166	.286	− 5.3
4	184	.282	0.0	356	176	.282	0.0
14	194	.288	+ 7.6	6	186	.286	+ 5.3
24	204	.308	+14.3	16	196	.300	+ 9.8
34	214	.336	+19.3	26	206	.320	+13.3
44	224	.372	+21.9	36	216	.344	+15.1
54	234	.409	+21.9	46	226	.370	+15.1
64	244	.444	+19.3	56	236	.394	+13.3
74	254	.473	+14.3	66	246	.414	+ 9.8
84	264	.491	+ 7.6	76	256	.427	+ 5.3
94	274	.498	0.0	86	266	.432	0.0

TABLE II.—CORRECTIONS FOR REFRACTION. (*Concluded.*)

Position Angle, p		$\frac{\sigma-s}{s}\times 10^3$	$\pi-p$	Position Angle, p		$\frac{\sigma-s}{s}\times 10^3$	$\pi-p$
PLATE 9.				**PLATE 10.**			
			″				″
281°	101°	+.580	0.0	275°	95°	+.498	0.0
291	111	.571	—10.8	285	105	.491	— 7.9
301	121	.544	—20.2	295	115	.471	—14.8
311	131	.504	—27.2	305	125	.442	—20.0
321	141	.454	—31.0	315	135	.405	—22.7
331	151	.400	—31.0	325	145	.367	—22.7
341	161	.350	—27.2	335	155	.330	—20.0
351	171	.310	—20.2	345	165	.301	—14.8
1	181	.283	—10.8	355	175	.280	— 7.9
11	191	.274	0.0	5	185	.274	0.0
21	201	.283	+10.8	15	195	.280	+ 7.9
31	211	.310	+20.2	25	205	.301	+14.8
41	221	.350	+27.2	35	215	.330	+20.0
51	231	.400	+31.0	45	225	.367	+22.7
61	241	.454	+31.0	55	235	.405	+22.7
71	251	.504	+27.2	65	245	.442	+20.0
81	261	.544	+20.2	75	255	.471	+14.8
91	271	.571	+10.8	85	265	.491	+ 7.9
101	281	.580	0.0	95	275	.498	0.0
PLATE 11.				**PLATE 12.**			
			″				″
275°	95°	+.518	0.0	268°	88°	+.452	0.0
285	105	.511	— 8.2	278	98	.447	— 5.9
295	115	.490	—15.4	288	108	.432	—11.1
305	125	.459	—20.7	298	118	.409	—14.9
315	135	.421	—23.6	308	128	.383	—17.0
325	145	.381	—23.6	318	138	.353	—17.0
335	155	.342	—20.7	328	148	.326	—14.9
345	165	.312	—15.4	338	158	.304	—11.1
355	175	.291	— 8.2	348	168	.289	— 5.9
5	185	.284	0.0	358	178	.284	0.0
15	195	.291	+ 8.2	8	188	.289	+ 5.9
25	205	.312	+15.4	18	198	.304	+11.1
35	215	.342	+20.7	28	208	.326	+14.9
45	225	.381	+23.6	38	218	.353	+17.0
55	235	.421	+23.6	48	228	.383	+17.0
65	245	.459	+20.7	58	238	.409	+14.9
75	255	.490	+15.4	68	248	.432	+11.1
85	265	.511	+ 8.2	78	258	.447	+ 5.9
95	275	.518	0.0	88	268	.452	0.0

TABLE III.—CORRECTIONS FOR PRECESSION, ETC., TO 1874 AND ZERO CORRECTIONS.

Plate No.	Precession, etc.		Zero Correction ½(East + West)	Special Correction Mean.	Adopted Mean.
	Position Angle Correction.	Distance Factor × 10³			
	″		′ ″	″	′ ″
1	− 2.9	−.0297	+20 31	−35	+19 56
2	− 2.9	−.0297	22 23	−38	21 45
3	− 2.9	−.0297	20 50	−31	20 19
4	+ 1.0	−.0363	19 16	−54	18 22
5	+ 1.0	−.0363	20 52	−44	20 8
6	+ 1.0	−.0363	14 39	−35	14 4
7	+16.6	+.0437	19 18	−41	18 37
8	+16.6	+.0437	19 36	−42	18 54
9	+11.5	+.0497	19 5	−52	18 13
10	+11.5	+.0497	17 22	−52	16 30
11	+11.2	+.0502	19 14	−36	18 38
12	+11.2	+.0502	+19 21	−41	+18 40

TABLE IV.—TANGENT CORRECTION.

This correction is always *negative*, and is here expressed in terms of the *fourth* decimal place of the micrometer readings.

Distance.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
20.	− 0	− 0	− 0	− 0	− 0	− 1	− 1	− 1	− 1	− 1
30.	2	2	2	2	2	3	3	3	3	3
40.	4	4	4	5	5	6	6	6	7	7
50.	8	8	8	9	9	10	10	11	11	12
60.	13	13	14	15	16	17	17	18	19	20
70.	21	22	23	24	25	26	27	28	30	31
80.	32	34	35	36	37	38	40	41	42	43
90.	45	46	48	50	52	53	55	57	59	61
100.	62	64	65	67	69	71	73	75	77	79
110.	81	83	85	87	90	93	95	98	100	103
120.	106	109	112	114	117	120	123	126	129	132
130.	−135	−138	−141	−145	−148	−151	−155	−158	−162	−165

TABLE V.—RESULTS OF MEASURES OF DISTANCE.

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	*s*			*σ*
1	11	.9218	.9090	675	+62	80	.9802	− 46	−.0334	123.9422
(2)	12	.8604	.9280	557	+62	94	.9536	− 52	−.0334	.9150
						Mean				123.9286
2	1	.0565	.0314	426	−35	118	.0851	− 11	+.0088	117.0928
(5)	2	.0288	.0212	480	−35	118	.0715	+ 31	+.0088	.0834
	4	.0233	.0122	512	−42	108	.0658	+135	+.0073	.0866
	5	.0191	.0307	603	−35	112	.0831	+ 21	+.0073	.0925
	7	.0681	.0718	508	+51	118	.1278	− 8	−.0290	.0980
	8	.0672	.0506	473	+51	118	.1134	+ 8	−.0290	.0852
	11	.0588	.0687	518	+59	118	.1234	− 44	−.0312	.0878
	12	.0788	.0600	490	+59	118	.1263	− 49	−.0312	.0902
						Mean				117.0896
3	1	.8405	.8320	308	−23	126	.8747	− 7	+.0092	75.8832
(37)	2	.8343	.8318	345	−23	126	.8751	+ 20	+.0092	.8863
	3	.8370	.8265	393	−23	126	.8787	+ 3	+.0092	.8882
	4	.8290	.8253	365	−28	119	.8700	+ 87	+.0077	.8864
	5	.8246	.8268	414	−28	120	.8736	+ 14	+.0077	.8827
	6	.8246	.8302	470	−28	126	.8815	− 39	+.0077	.8853
	7	.8677	.8751	377	+33	125	.9222	− 5	−.0305	.8912
	8	.8702	.8771	326	+33	125	.9193	+ 5	−.0305	.8893
	9	.8731	.8745	434	+38	118	.9301	− 30	−.0327	.8944
	10	.8802	.86 8	376	+38	119	.9221	+ 11	−.0327	.8905
	11	.8722	.8724	392	+38	126	.9251	− 28	−.0329	.8894
	12	.8680	.8923	342	+38	120	.9275	− 32	−.0329	.8914
						Mean				75.8882
4	1	.6812	.6768	297	−24	125	.7156	− 8	+.0090	79.7238
(4)	2	.6670	.6668	336	−24	126	.7075	+ 21	+.0090	.7186
	3	.6482	.6546	393	−24	125	.6976	+ 3	+.0090	.7069
	4	.6526	.6361	357	−29	122	.6861	+ 92	+.0075	.7028
	5	.6528	.6546	421	−29	121	.7015	+ 15	+.0075	.7105
	6	.6520	.6515	500	−29	125	.7082	− 41	+.0075	.7116
	7	.7078	.7126	359	+35	126	.7590	− 5	−.0297	.7288
	8	.7097	.7233	330	+35	126	.7624	+ 5	−.0297	.7332
	9	.7018	.7226	382	+40	122	.7634	− 31	−.0319	.7284
	10	.7171	.7008	355	+40	122	.7575	+ 12	−.0319	.7268
	11	.7009	.7205	368	+40	126	.7609	− 30	−.0321	.7258
	12	.7038	.7110	340	+48	126	.7548	− 34	−.0321	.7193
						Mean				79.7197
5	1	.4787	.5182	383	−36	112	.5337	− 12	+.0062	120.5387
(7)	2	.4734	.4791	408	−36	108	.5136	+ 32	+.0062	.5230
	4	.4728	.4666	425	−44	108	.5079	+139	+.0052	.5270
	7	.5138	.5006	406	+53	109	.5533	− 8	−.0206	.5319
	9	.5070	.5259	389	+60	109	.5615	− 47	−.0220	.5348
						Mean				120.5311

TABLE VI.—RESULTS OF MEASURES OF ANGLE.

Plate	Observed Position Angle.		Zero Correction plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Final Corrected Angle. π
	East.	West.					
	° ′ ″	′ ″	′ ″	″	° ′ ″	′ ″	° ′ ″
11	351 38 20	39 25	18 38	+10	261 57 41	− 0 2	261 57 53
12	40 50	41 45	18 40	+ 4	262 0 2	− 0 2	57 22
				Mean	261 58 52		261 57 38
1	331 22 50	23 32	19 56	+11	241 43 18	+ 0 6	241 43 58
2	19 8	21 30	21 45	+15	42 20	+ 0 6	43 33
4	24 22	25 7	18 22	+16	43 22	+ 0 5	43 56
5	21 45	23 11	20 8	+17	42 53	+ 0 5	44 1
7	23 43	25 45	18 37	+20	43 41	− 0 21	44 23
8	24 50	27 3	18 54	+12	45 3	− 0 21	44 23
11	24 58	25 45	18 38	+22	44 22	− 0 22	44 14
12	27 10	28 17	18 40	+13	46 37	− 0 22	43 37
				Mean	241 43 57		241 44 1
1	2 29 48	31 34	19 56	+ 4	272 50 41	− 0 4	272 51 11
2	27 40	28 38	21 45	+ 2	49 56	− 0 4	50 59
3	31 3	32 6	20 19	− 4	51 50	− 0 4	51 25
4	31 57	34 8	18 22	− 2	51 22	− 0 4	51 47
5	30 6	30 50	20 8	− 6	50 30	− 0 4	51 29
6	30 12	31 32	14 4	−17	44 39	− 0 4	51 42
7	30 26	31 32	18 37	+ 2	49 38	+ 0 14	50 55
8	31 48	33 13	18 54	− 3	51 22	+ 0 14	51 17
9	33 15	33 48	18 13	+ 9	51 54	+ 0 15	51 13
10	33 42	35 27	16 30	+ 2	51 6	+ 0 15	51 6
11	31 26	32 34	18 38	+ 2	50 40	+ 0 15	51 9
12	34 28	34 54	18 40	− 3	53 18	+ 0 15	50 55
				Mean	272 50 35		272 51 16
1	335 57 10	57 27	19 56	+10	246 17 24	+ 0 7	246 18 5
2	54 33	55 42	21 45	+13	17 5	+ 0 7	18 19
3	57 25	58 13	20 19	+16	18 24	+ 0 7	18 10
4	58 8	00 0	18 22	+17	17 43	+ 0 6	18 18
5	56 1	57 2	20 8	+15	16 55	+ 0 6	18 4
6	56 45	58 5	14 4	+14	11 43	+ 0 6	18 56
7	57 48	59 20	18 37	+18	17 29	− 0 24	18 8
8	59 23	00 38	18 54	+10	19 5	− 0 24	18 22
9	336 00 2	1 50	18 13	+29	19 38	− 0 26	18 16
10	1 38	2 42	16 30	+19	18 59	− 0 26	18 18
11	335 58 39	59 45	18 38	+20	18 10	− 0 26	17 58
12	336 1 27	3 8	18 40	+12	21 10	− 0 26	18 6
				Mean	246 17 49		246 18 15
1	303 48 8	49 33	19 56	+ 8	214 8 54	+ 0 12	214 9 40
2	45 14	46 12	21 45	+14	7 41	+ 0 12	9 0
4	48 57	51 5	18 22	+17	8 40	+ 0 10	9 19
7	49 6	50 40	18 37	+19	8 49	− 0 41	9 11
9	51 40	54 10	18 13	+22	11 30	− 0 44	9 50
				Mean	214 9 7		214 9 24

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	*s*			σ
6	1	.6300	.6668	206	—18	108	.6767	— 6	+.0079	60.6840
(6)	7	.6482	.6756	237	+27	104	.6974	— 4	—.0260	.6710
	8	.6311	.6802	229	+27	104	.6903	+ 4	—.0260	.6647
	11	.6501	.6848	242	+30	104	.7037	— 23	—.0280	.6734
	12	.6314	.7006	234	+30	104	.7015	— 26	—.0280	.6709
						Mean				60.6728
7	1	.4126	.4174	280	—27	132	.4491	— 9	+ 0058	89.4540
(8)	2	.4182	.4170	297	—27	132	.4534	+ 24	+.0058	.4616
	3	.4091	.4190	329	—27	135	.4533	+ 3	+.0058	.4594
	4	.4038	.3977	307	—32	132	.4371	+103	+.0049	.4523
	7	.4462	.4322	292	+39	135	.4814	— 6	—.0193	.4615
	9	.4520	.4428	276	+44	132	.4882	— 35	—.0207	.4640
	11	.4362	.4448	291	+45	135	.4832	— 33	—.0208	.4591
	12	.4324	.4485	297	+45	135	.4838	— 38	—.0208	.4592
						Mean				89.4589
8	1	.4792	.4746	226	—17	98	.5063	— 6	+.0063	58.5120
(36)	2	.4758	.4712	235	—17	96	.5037	+ 16	+.0063	.5116
	3	.4737	.4681	245	—17	98	.5023	+ 2	+.0063	.5088
	4	.4762	.4686	240	—21	92	.5023	+ 67	+.0052	.5142
	5	.4792	.4766	246	—21	95	.5087	+ 11	+.0052	.5150
	6	.4765	.4783	253	—21	98	.5092	— 30	+.0052	.5114
	7	.4964	.4917	249	+26	95	.5298	— 4	—.0208	.5086
	8	.5143	.5112	209	+26	95	.5446	+ 4	—.0208	.5242
	9	.4998	.5047	297	+29	94	.5430	— 23	—.0223	.5184
	10	.5128	.5015	248	+29	90	.5427	+ 8	—.0223	.5212
	11	.4968	.5012	257	+29	95	.5359	— 22	—.0224	.5113
	12	.4998	.4960	221	+29	95	.5312	— 25	—.0224	.5063
						Mean				58.5136
9	1	.6254	.6327	120	— 9	—12	.6387	— 3	+.0093	29.6477
(1)	2	.6082	.6068	134	— 9	— 9	.6189	+ 8	+.0093	.6290
	3	.6143	.6124	154	— 9	—12	.6264	+ 1	+.0093	.6358
	4	.6158	.5907	143	—11	—16	.6147	+ 34	+.0077	.6258
	5	.6198	.6114	162	—11	—13	.6292	+ 5	+.0077	.6374
	6	.5928	.6051	185	—11	—12	.6149	— 15	+.0077	.6211
	7	.6592	.6639	147	+13	— 9	.6764	— 2	—.0307	.6455
	8	.6626	.6476	128	+13	— 9	.6681	+ 2	—.0307	.6376
	9	.6701	.6652	169	+15	—15	.6844	— 12	—.0329	.6503
	10	.6486	.6434	147	+15	—16	.6604	+ 4	—.0329	.6279
	11	.6690	.6858	153	+15	— 9	.6931	— 11	—.0331	.6589
	12	.6680	.6870	134	+15	—13	.6909	— 13	—.0331	.6565
						Mean				29 6394

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle.		Zero Correction plus precession, etc.	Refrac.	Corrected Mean. p	Proper Motion.	Final Corrected Angle π
	East.	West.					
1	319° 8′ 16″	10′ 5″	19′ 56″	+11″	229° 29′ 17″	+ 0′ 18″	229° 30′ 9″
7	11 20	12 14	18 37	+22	30 46	− 0 59	30 50
8	11 21	13 29	18 54	+14	31 33	− 0 59	30 15
11	11 43	12 58	18 38	+24	31 23	− 1 3	30 34
12	12 53	15 58	18 40	+16	33 22	− 1 3	29 41
				Mean	229 31 16		229 30 18
1	300 40 20	41 54	19 56	+ 6	211 1 9	+ 0 17	211 2 0
2	38 36	38 53	21 45	+12	0 42	+ 0 17	2 6
3	41 35	41 28	20 19	+21	2 12	+ 0 17	2 8
4	41 25	43 31	18 22	+16	1 6	+ 0 14	1 49
7	43 42	44 35	18 37	+18	3 3	− 0 57	3 9
9	45 50	46 45	18 13	+19	4 49	− 1 1	2 52
11	43 47	44 37	18 38	+18	3 8	− 1 2	2 20
12	46 12	47 45	18 40	+15	5 53	− 1 2	2 13
				Mean	211 2 45		211 2 20
1	39 59 28	00 26	19 56	− 9	310 19 45	− 0 24	310 19 55
2	56 38	57 52	21 45	−15	18 45	− 0 24	19 28
3	40 0 35	2 8	20 19	−23	21 18	− 0 24	20 33
4	1 48	3 2	18 22	−18	20 29	− 0 20	20 38
5	39 59 44	59 48	20 8	−26	19 28	− 0 20	20 11
6	59 30	00 51	14 4	−34	13 41	− 0 20	20 28
7	58 3	59 55	18 37	−20	17 16	+ 1 20	19 39
8	59 12	59 50	18 54	−15	18 10	+ 1 20	19 11
9	40 1 2	1 44	18 13	−27	19 9	+ 1 25	19 38
10	1 30	3 46	16 30	−21	18 47	+ 1 25	19 57
11	39 59 5	59 40	18 38	−22	17 38	+ 1 26	19 18
12	40 1 25	2 50	18 40	−17	20 31	+ 1 26	19 19
				Mean	310 18 45		310 19 51
1	0 27 0	25 25	19 56	+ 5	270 46 13	− 0 9	270 46 38
2	24 22	25 12	21 45	+ 3	46 35	− 0 9	47 33
3	28 12	27 34	20 19	− 3	48 8	− 0 9	47 38
4	27 45	27 18	18 22	+ 1	45 55	− 0 7	46 17
5	27 47	24 28	20 8	− 5	46 11	− 0 7	47 7
6	26 40	27 42	14 4	−15	41 0	− 0 7	48 0
7	28 26	28 50	18 37	+ 3	47 18	+ 0 29	48 50
8	28 2	31 00	18 54	− 3	48 22	+ 0 29	48 32
9	30 8	32 55	18 13	+12	49 57	+ 0 32	49 33
10	29 28	32 32	16 30	+ 4	47 34	+ 0 32	47 51
11	27 57	27 23	18 38	+ 4	46 22	+ 0 32	47 8
12	30 48	31 5	18 40	− 2	49 35	+ 0 32	47 29
				Mean	270 46 56		270 47 43

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean. s	Scale Variation.	Proper Motion.	Final Corrected Distance. σ
		East.	West.	Refrac.	Aberr.	Scale.				
10	1	.5694	.5805	71	— 6	82	.5897	— 2	+.0092	18.5987
(3)	2	.5719	.5707	80	— 6	82	.5869	+ 5	+.0092	.5966
	3	.5654	.5760	93	— 6	82	.5876	+ 1	+.0092	.5969
	4	.5708	.5648	86	— 7	80	5837	+ 21	+.0076	.5934
	5	.5722	.5796	100	— 7	79	.5931	+ 3	+.0076	.6010
	6	.5602	.5624	118	— 7	82	.5806	— 9	+.0076	.5873
	7	.6199	.6315	86	+ 8	84	.6435	— 1	—.0303	.6131
	8	.6193	.6273	78	+ 8	83	.6402	+ 1	—.0303	.6100
	9	.6193	.6354	93	+ 9	80	.6455	— 7	—.0325	.6123
	10	.6271	.6077	85	+ 9	80	.6348	+ 3	—.0325	.6026
	11	.6221	.6370	88	+ 9	83	.6476	— 7	— 0327	.6142
	12	.6156	.6302	81	+ 9	79	.6397	— 8	—.0327	.6062
						Mean				18.6027
11	1	.8040	.8069	321	—31	114	.8386	— 10	+.0022	105.8398
(13)	2	.7998	.7846	320	—31	113	.8251	+ 28	+.0022	.8301
	3	.8079	.7994	323	—31	114	.8369	+ 4	+.0022	.8395
	4	.7984	.7982	319	—38	113	.8304	+122	+.0018	.8444
	5	.7858	.8043	329	—38	114	.8283	+ 19	+.0018	.8320
	6	.8105	.7979	351	—38	114	.8396	— 54	+.0018	.8360
	7	.8096	.8005	300	+46	111	.8434	— 7	—.0072	.8355
	8	.8069	.7925	302	+46	111	.8383	+ 7	—.0072	.8318
	9	.8170	.8218	295	+53	115	.8584	— 41	—.0077	.8466
	10	.8217	.7905	292	+53	113	.8446	+ 15	—.0077	.8384
	11	.8097	.8067	302	+53	114	.8478	— 39	—.0077	.8362
	12	.8047	.7993	304	+53	114	.8418	— 45	—.0077	.8296
						Mean				105.8366
12	3	.0888	.0700	43	— 4	48	.0881	0	+.0053	12.0934
(9)	6	.0682	.0690	52	— 4	48	.0782	— 6	+.0044	.0820
	7	.0909	.1093	38	+ 5	48	.1092	— 1	—.0176	.0916
•	11	.1478	.1806	39	+ 6	48	.1735	— 5	—.0190	.1540
						Mean				12.1052
13	1	.0319	.0384	73	— 7	112	.0529	— 2	+.0024	24.0551
(10)	2	.0380	.0307	72	— 7	111	.0518	+ 6	+.0024	.0584
	3	.0364	.0349	73	— 7	112	.0533	+ 1	+.0024	.0558
	4	.0286	.0345	72	— 9	111	.0489	+ 28	+.0020	.0537
	5	.0258	.0495	75	— 9	112	.0554	+ 4	+.0020	.0578
	6	.0384	.0380	80	— 9	112	.0564	— 12	+.0020	.0572
	7	.0418	.0258	68	+11	111	.0527	— 2	—.0078	.0447
	8	.0542	.0408	69	+11	111	.0665	+ 2	—.0078	.0589
	9	.0473	.0495	67	+12	111	.0673	— 9	—.0084	.0580
	10	.0457	.0405	66	+12	111	.0621	+ 3	—.0084	.0540
	11	.0405	.0475	69	+12	112	.0632	— 9	—.0085	.0538
	12	.0508	.0479	69	+12	110	.0684	— 10	—.0085	.0589
						Mean				24.0552

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle.		Zero Correction plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Final Corrected Angle. *π*
	East.	West.					
1	340° 10′ 45″	9′ 22″	19′ 56″	+10″	250° 30′ 9″	+ 0′ 22″	250° 31′ 5″
2	6 59	7 55	21 45	+12	29 23	+ 0 22	30 52
3	10 50	10 13	20 19	+14	31 5	+ 0 22	31 6
4	9 37	12 42	18 22	+12	29 43	+ 0 18	30 30
5	8 42	11 48	20 8	+12	30 35	+ 0 18	31 56
6	11 7	10 51	14 4	+10	25 13	+ 0 18	32 38
7	14 10	12 28	18 37	+16	32 12	— 1 13	32 2
8	15 52	18 55	18 54	+ 8	36 25	— 1 13	34 53
9	15 36	14 45	18 13	+26	33 50	— 1 18	31 36
10	18 27	19 15	16 30	+17	35 38	— 1 18	34 5
11	13 54	13 57	18 38	+18	32 51	— 1 19	31 46
12	15 35	17 13	18 40	+10	35 14	— 1 19	31 17
				Mean	250 31 52		250 31 59
1	275 37 43	39 10	19 56	— 2	185 58 20	+ 0 18	185 59 12
2	35 33	36 32	21 45	+ 1	57 48	+ 0 18	59 13
3	38 0	39 25	20 19	+ 5	59 6	+ 0 18	59 3
4	38 55	40 35	18 22	+ 3	58 10	+ 0 15	58 54
5	36 16	38 15	20 8	+ 9	57 33	+ 0 15	58 51
6	36 45	37 52	14 4	+19	51 41	+ 0 15	59 3
7	40 10	41 13	18 37	+ 1	59 20	— 1 0	59 23
8	40 58	42 47	18 54	+ 5	186 0 51	— 1 0	59 32
9	42 15	44 20	18 13	— 5	1 26	— 1 4	59 26
10	43 28	44 48	16 30	+ 1	0 39	— 1 4	59 20
11	40 46	42 15	18 38	0	0 9	— 1 5	59 18
12	43 52	45 30	18 40	+ 5	3 26	— 1 5	59 43
				Mean	185 59 2		185 59 15
3	296 47 36	44 50	20 19	+20	207 6 52	+ 2 12	207 8 43
6	43 50	46 28	14 4	+34	206 59 47	+ 1 49	8 43
7	297 00 30	00 55	18 37	+16	207 19 35	— 7 16	13 22
11	296 57 10	59 18	18 38	+16	17 8	— 7 50	9 32
				Mean	207 10 50		207 10 5
1	276 49 34	50 6	19 56	— 2	187 9 44	+ 1 18	187 11 36
2	45 12	46 0	21 45	+ 2	7 23	+ 1 18	9 48
3	48 37	48 27	20 19	+ 7	8 58	+ 1 18	9 55
4	48 28	48 32	18 22	+ 4	6 56	+ 1 5	8 30
5	48 32	51 20	20 8	+11	10 15	+ 1 5	12 23
6	47 48	49 27	14 4	+21	3 3	+ 1 5	11 15
7	55 40	57 54	18 37	+ 2	15 26	— 4 18	12 11
8	56 38	59 32	18 54	+ 6	17 5	— 4 18	12 28
9	57 27	58 28	18 13	— 7	16 3	— 4 37	10 30
10	59 31	57 45	16 30	+ 2	15 10	— 4 37	10 18
11	57 23	58 26	18 38	+ 2	16 35	— 4 39	12 10
12	277 00 42	4 8	18 40	+ 5	21 10	— 4 39	13 53
				Mean	187 12 19		187 11 15

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	*s*			*σ*
14	1	.9921	.9886	241	—23	123	.0214	— 8	+.0015	79.0221
(11)	2	.9942	.9893	238	—23	123	.0225	+21	+.0015	.0261
	3	.9912	.9902	239	—23	123	.0215	+ 3	+.0015	.0233
	4	.9856	.9872	237	—29	123	.0164	+91	+.0012	.0267
	5	.9839	.9894	241	—29	123	.0170	+14	+.0012	.0196
	6	.0009	.9952	251	—29	123	.0295	—40	+.0012	.0267
	7	.0067	.9917	224	+35	123	.0343	— 5	—.0048	.0290
	8	.9980	.9899	224	+35	123	.0290	+ 5	—.0048	.0247
	9	.0037	.0073	224	+39	124	.0411	—31	—.0051	.0329
	10	.0043	.0031	218	+39	123	.0386	+11	—.0051	.0346
	11	.0001	.0040	227	+40	122	.0378	—29	—.0052	.0297
	12	.9977	.9912	225	+40	123	.0302	—33	—.0052	.0217
						Mean				79.0264
15						*Bradley 3077*				
16	1	.8460	.8478	246	—24	128	.8787	— 8	+.0010	79.8789
(12)	2	.8421	.8386	243	—24	128	.8720	+21	+.0010	.8751
	3	.8450	.8397	240	—24	128	.8737	+ 3	+.0010	.8750
	4	.8380	.8354	240	—29	126	.8672	+92	+.0008	.8772
	5	.8317	.8400	241	—29	128	.8667	+15	+.0008	.8690
	6	.8454	.8426	247	—29	128	.8755	—41	+.0008	.8722
	7	.8456	.8497	227	+35	126	.8833	— 5	—.0032	.8796
	8	.8386	.8396	227	+35	126	.8753	+ 5	—.0032	.8726
	9	.8440	.8532	233	+40	126	.8854	—31	—.0034	.8789
	10	.8516	.8420	222	+40	126	.8825	+12	—.0034	.8803
	11	.8385	.8405	231	+40	126	.8761	—30	—.0034	.8697
	12	.8381	.8349	227	+40	126	.8727	—34	—.0034	.8659
						Mean				79.8746
17	1	.1610	.1509	118	—12	101	.1763	— 4	—.0026	39.1733
(34)	2	.1661	.1638	119	—12	102	.1855	+10	—.0026	.1839
	3	.1664	.1624	121	—12	101	.1850	+ 1	—.0026	.1825
	4	.1569	.1605	119	—14	102	.1790	+45	—.0022	.1813
	5	.1613	.1573	124	—14	102	.1801	+ 7	—.0022	.1786
	6	.1685	.1719	134	—14	101	.1919	—20	—.0022	.1877
	7	.1522	.1574	112	+17	111	.1784	— 3	+.0086	.1867
	8	.1550	.1482	114	+17	111	.1754	+ 3	+.0086	.1843
	9	.1546	.1376	108	+19	111	.1696	—15	+.0121	.1802
	10	.1376	.1481	108	+19	105	.1656	+ 6	+.0121	.1783
	11	.1445	.1444	112	+20	101	.1673	—15	+.0122	.1780
	12	.1461	.1446	113	+20	102	.1684	—17	+.0122	.1789
						Mean				39.1811

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle.		Zero Correction plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Final Corrected Angle *π*
	East.	West.					
1	271° 7′ 32″	9′ 8″	19′ 56″	— 5″	181° 28′ 11″	+ 0′ 25″	181° 29′ 10″
2	5 10	6 43	21 45	— 2	27 40	+ 0 25	29 12
3	8 5	8 55	20 19	+ 4	28 53	+ 0 25	28 57
4	8 44	10 50	18 22	+ 1	28 10	+ 0 20	28 59
5	7 22	8 8	20 8	+ 5	27 58	+ 0 20	29 21
6	6 21	8 5	14 4	+15	21 32	+ 0 20	28 59
7	10 35	11 40	18 37	— 2	29 43	— 1 21	29 25
8	11 18	12 33	18 54	+ 3	30 53	— 1 21	29 13
9	12 55	15 18	18 13	—10	32 9	— 1 27	29 46
10	14 3	14 57	16 30	— 3	30 57	— 1 27	29 15
11	11 34	12 30	18 38	— 5	30 35	— 1 28	29 21
12	14 28	15 20	18 40	+ 2	33 36	— 1 28	29 30
				Mean	181 29 11		181 29 16
1	268 8 40	10 24	19 56	— 5	178 29 23	+ 0 25	178 30 22
2	6 23	7 8	21 45	— 2	28 29	+ 0 25	30 1
3	9 17	10 12	20 19	+ 1	30 4	+ 0 25	30 8
4	9 52	11 38	18 22	— 2	29 5	+ 0 20	29 54
5	7 56	9 50	20 8	+ 4	29 5	+ 0 20	30 28
6	7 23	9 14	14 4	+13	22 35	+ 0 20	30 2
7	11 22	13 27	18 37	— 4	30 57	— 1 21	30 39
8	12 40	14 3	18 54	+ 1	32 17	— 1 21	30 37
9	13 28	15 57	18 13	—14	32 41	— 1 27	30 18
10	15 0	15 57	16 30	— 2	31 56	— 1 27	30 14
11	12 38	13 43	18 38	— 5	31 44	— 1 27	30 31
12	14 28	16 47	18 40	0	34 18	— 1 27	30 13
				Mean	178 30 13		178 30 17
1	98 30 35	31 20	19 56	— 2	8 50 52	— 0 47	8 50 39
2	27 55	30 13	21 45	+ 2	50 51	— 0 47	51 11
3	31 38	31 55	20 19	+ 9	52 15	— 0 47	51 7
4	33 5	33 0	18 22	+ 5	51 29	— 0 39	51 19
5	29 6	30 26	20 8	+ 13	50 7	— 0 39	50 31
6	29 42	30 30	14 4	+ 23	44 33	— 0 39	51 1
7	26 3	28 3	18 37	+ 11	45 51	+ 2 35	49 29
8	27 41	28 27	18 54	+ 7	47 5	+ 2 35	49 21
9	28 47	30 28	18 13	— 3	47 48	+ 2 47	49 39
10	29 34	31 40	16 30	+ 3	47 10	+ 2 47	49 42
11	27 50	29 25	18 38	+ 3	47 19	+ 2 48	50 21
12	29 18	30 12	18 40	+ 6	48 31	+ 2 48	48 41
				Mean	8 48 39		8 50 15

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	*s*			*σ*
18 (33)	1	.3692	.3590	88	− 8	113	.3832	− 3	−.0053	28.3776
	3	.3860	.3727	101	− 8	113	.3998	+ 1	−.0053	.3946
	4	.3821	.3729	95	−10	124	.3982	+ 33	−.0044	.3971
	6	.3806	.3646	122	−10	112	.3948	− 14	−.0044	.3890
	11	.3330	.3232	90	+14	113	.3496	− 11	+.0188	.3673
	12	.3444	.3357	91	+14	113	.3616	− 12	+.0188	.3792
						Mean				28.3841
19 (14)	1	.9604	.9622	182	−17	103	.9871	− 5	−.0013	55.9853
	2	.9638	9538	178	−17	103	.9837	+ 15	−.0013	.9839
	3	.9560	.9669	174	−17	104	.9865	+ 2	−.0013	.9854
	4	.9503	.9490	176	−20	104	.9747	+ 64	−.0011	.9800
	5	.9515	.9655	172	−20	103	.9830	+ 10	−.0011	.9829
	6	.9636	.9625	169	−20	103	.9872	− 28	−.0011	.9833
	7	.9464	.9467	172	+24	100	.9752	− 4	+.0042	.9790
	8	.9410	.9460	162	+24	100	.9711	+ 4	+.0042	.9757
	9	.9478	.9522	188	+28	100	.9806	− 22	+.0045	.9829
	10	.9449	.9497	168	+28	103	.9763	+ 8	+.0045	.9816
	11	.9503	.9477	176	+28	106	.9790	− 21	+.0046	.9815
	12	.9530	.9375	165	+28	103	.9738	− 24	+.0046	.9760
						Mean				55.9815
20 (35)	1	.5073	.5128	269	−27	134	.5432	− 9	−.0033	89.5390
	2	.5142	.5126	273	−27	135	.5471	+ 24	−.0033	.5462
	3	.5201	.5099	284	−27	134	.5497	+ 3	−.0033	.5467
	4	.5090	.5036	275	−32	134	.5396	+103	−.0027	.5472
	5	.5176	.5086	291	−32	134	.5480	+ 16	−.0027	.5469
	6	.5228	.5256	322	−32	134	.5622	− 46	−.0027	.5549
	7	.4895	.4994	256	+39	132	.5327	− 6	+.0108	.5429
	8	.4880	.4998	264	+39	133	.5331	+ 6	+.0108	.5445
	9	.4948	.4784	247	+44	129	.5242	− 35	+.0116	.5323
	10	.4964	.4906	249	+44	134	.5318	+ 13	+.0116	.5447
	11	.4836	.4807	259	+45	134	.5216	− 33	+.0117	.5300
	12	.4925	.4884	266	+45	134	.5306	− 38	+.0117	.5385
						Mean				89.5428
21 (22)	1	.9995	.0222	122	−10	119	.0337	− 3	−.0059	32.0275
	3	.0215	.0238	130	−10	119	.0463	+ 1	−.0059	.0405
	4	.0225	.0284	128	−12	124	.0492	+ 37	−.0049	.0480
	6	.0242	.0170	132	−12	119	.0443	− 16	−.0049	.0378
	7	.9806	.9690	132	+14	121	.0013	− 2	+.0195	.0206
	8	.9991	.9762	112	+14	121	.0122	+ 2	+.0195	.0319
	9	.9821	.9786	157	+16	122	.0097	− 12	+.0209	.0294
	11	.9916	.9710	137	+16	121	.0085	− 12	+.0210	.0283
	12	.0040	.9812	118	+16	121	.0179	− 14	+ 0210	.0375
						Mean				32.0335

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac	Corrected Mean. p	Proper Motion.	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	° ′ ″	′ ″	° ′ ″
1	116 31 5	31 42	19 56	+ 5	26 51 24	− 0 56	26 51 2
3	34 8	34 50	20 19	+19	55 7	− 0 56	53 50
4	35 7	38 0	18 22	+14	55 9	− 0 47	54 51
6	32 25	33 14	14 4	+34	47 28	− 0 47	53 48
11	29 35	29 14	18 38	+16	48 18	+ 3 20	51 52
12	32 24	30 35	18 40	+ 14	50 23	+ 3 20	51 5
				Mean	26 51 18		26 52 45
1	254 20 16	22 27	19 56	− 9	164 41 9	+ 0 35	164 42 18
2	18 45	19 38	21 45	−10	40 47	+ 0 35	42 29
3	21 12	21 48	20 19	− 9	41 40	+ 0 35	41 54
4	22 3	24 22	18 22	−10	41 24	+ 0 29	42 22
5	18 50	22 6	20 8	− 8	40 28	+ 0 29	42 0
6	20 30	21 18	14 4	− 5	34 53	+ 0 29	42 29
7	24 34	25 40	18 37	−14	43 30	− 1 54	42 39
8	25 47	26 45	18 54	− 6	45 4	− 1 54	42 51
9	27 8	28 50	18 13	−24	45 48	− 2 3	42 49
10	29 26	28 11	16 30	−15	45 3	− 2 3	42 45
11	26 18	27 40	18 38	−16	45 21	− 2 3	43 32
12	27 40	29 58	18 40	− 8	47 21	− 2 3	42 40
				Mean	164 42 42		164 42 34
1	102 41 28	43 28	19 56	0	13 2 24	− 0 20	13 2 38
2	39 38	40 45	21 45	+ 5	2 2	− 0 20	2 49
3	42 35	43 28	20 19	+ 11	3 32	− 0 20	2 51
4	43 27	45 10	18 22	+ 8	2 49	− 0 16	3 2
5	40 45	42 10	20 8	+15	1 51	− 0 16	2 38
6	41 10	41 42	14 4	+ 27	12 55 57	− 0 16	2 48
7	40 53	41 48	18 37	+ 7	13 0 5	+ 1 6	2 14
8	42 3	43 8	18 54	+ 8	1 38	+ 1 6	2 25
9	43 27	44 25	18 13	+ 3	2 12	+ 1 10	1 26
10	43 50	45 32	16 30	+ 6	1 17	+ 1 10	2 12
11	41 32	42 47	18 38	+ 6	0 53	+ 1 11	2 18
12	43 56	45 30	18 40	+ 8	3 31	+ 1 11	2 4
				Mean	13 1 31		13 2 27
1	223 10 27	13 8	19 56	−10	133 31 34	+ 0 48	133 32 56
3	10 35	12 2	20 19	−22	31 15	+ 0 48	31 42
4	11 24	15 35	18 22	−19	31 32	+ 0 39	32 40
6	9 13	11 20	14 4	−33	23 48	+ 0 39	31 34
7	13 28	14 32	18 37	−21	32 16	− 2 36	30 43
8	15 6	17 0	18 54	−15	34 42	− 2 36	31 47
9	16 50	20 25	18 13	−28	36 23	− 2 48	32 39
11	17 5	17 45	18 38	−23	35 40	− 2 49	33 5
12	16 7	17 37	18 40	−17	35 15	− 2 49	29 48
				Mean	133 32 29		133 31 53

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate	Observed Dist.		Corrections for			Corrected Mean	Scale Variation.	Proper Motion.	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	*s*		—	*σ*
22	8	.2376	.2377	295	+45	125	.2775	+ 7	+.0040	102.2822
(15)	11	.2489	.2607	320	+51	134	.2987	—38	+.0043	.2992
	12	.2472	.2366	301	+51	125	.2830	—43	+.0043	.2830
						Mean				102.2881
23	1	.5766	.5912	410	—37	84	.6175	— 12	—.0016	124.6147
(16)	2	.5746	.5729	404	—37	84	.6068	+ 33	—.0016	.6085
	4	.5400	.5510	397	—45	84	.5770	+144	—.0013	.5901
	5	.5488	.5608	389	—45	82	.5853	+ 23	—.0013	.5863
	6	.5830	.6004	381	—45	82	.6214	— 63	—.0013	.6138
	7	.5582	.5378	392	+54	84	.5889	— 8	+.0054	.5935
	8	.5514	.5656	364	+54	85	.5967	+ 8	+.0054	.6029
	10	.5485	.5727	385	+62	84	.6016	+ 18	+.0058	.6092
	11	.5523	.5609	397	+63	84	.5989	— 46	+.0058	.6001
	12	.5545	.5378	370	+63	104	.5878	— 53	+.0058	.5883
						Mean				124 6007
24	1	.5444	.5442	238	—20	107	.5750	— 6	—.0043	66.5701
(21)	2	.5444	.5316	241	—20	107	.5690	+ 18	—.0043	.5665
	3	.5391	.5332	240	—20	106	.5669	+ 2	—.0043	.5628
	4	.5466	.5563	240	—24	109	.5821	+ 77	—.0035	.5863
	5	.5401	.5340	237	—24	107	.5672	+ 12	—.0035	.5649
	6	.5583	.5482	234	—24	107	.5832	— 34	—.0035	.5763
	7	.5331	.5149	245	+29	110	.5606	— 5	+.0140	.5741
	8	.5166	.5144	214	+29	110	.5490	+ 5	+.0140	.5635
	9	.5112	.4964	290	+33	110	.5453	— 26	+.0150	.5577
	11	.5372	.5161	253	+33	107	.5641	— 25	+.0151	.5767
	12	.5177	.5113	223	+33	106	.5489	— 28	+.0151	.5612
						Mean				66.5691
25	1	.5484	.5453	396	—35	123	.5851	— 11	—.0022	118 5818
(17)	2	.5400	.5337	391	—35	123	.5746	+ 32	—.0022	.5756
	3	.5540	.5545	383	—35	123	.5913	+ 4	—.0022	.5895
	4	.5350	.5390	386	—43	123	.5735	+137	—.0018	.5854
	5	.5296	.5345	378	—43	123	.5677	+ 22	—.0018	.5681
	7	.5290	.5176	383	+52	123	.5690	— 8	+.0071	.5753
	8	.5395	.5224	352	+52	124	.5737	+ 8	+.0071	.5816
	9	.5226	.5122	428	+59	123	.5683	— 46	+.0076	.5713
	11	.5294	.5288	393	+60	123	.5766	— 44	+.0076	.5798
	12	.5205	.5310	358	+59	123	.5697	— 50	+.0076	.5723
						Mean				118.5781

TABLE VI.—RESULTS OF MEASURES OF ANGLE. *(Continued.)*

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. p	Proper Motion.	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	° ′ ″	′ ″	° ′ ″
8	254 45 34	46 15	18 54	— 6	165 4 42	— 1 3	165 3 20
11	44 57	46 50	18 38	—15	4 17	— 1 8	3 23
12	47 47	48 55	18 40	— 8	6 53	— 1 8	3 7
				Mean	165 5 17		165 3 17
1	252 10 42	11 42	19 56	—10	162 30 58	+ 0 16	162 31 48
2	8 48	9 52	21 45	—10	30 55	+ 0 16	32 18
4	11 56	14 7	18 22	—11	31 13	+ 0 13	*31 55
5	9 28	11 32	20 8	—10	30 28	+ 0 13	31 44
6	9 56	11 8	14 4	— 5	24 31	+ 0 13	31 51
7	13 3	14 13	18 37	—15	32 0	— 0 52	32 11
8	13 53	15 27	18 54	— 7	33 27	— 0 52	32 16
10	16 26	17 50	16 30	—16	33 22	— 0 56	32 11
11	13 38	15 12	18 38	—17	32 46	— 0 56	32 4
12	16 2	18 13	18 40	— 8	35 40	— 0 56	32 6
				Mean	162 31 32		162 32 2
1	235 18 8	19 22	19 56	—11	145 38 30	+ 0 26	145 39 30
2	15 38	16 32	21 45	—16	37 34	+ 0 26	39 7
3	18 42	19 8	20 19	—20	38 54	+ 0 26	38 59
4	19 20	19 53	18 22	—17	37 41	+ 0 22	38 32
5	16 34	18 50	20 8	—22	37 28	+ 0 22	38 53
6	16 48	18 18	14 4	—27	31 10	+ 0 22	38 39
7	20 35	21 45	18 37	—21	39 26	— 1 27	39 2
8	21 48	23 18	18 54	—14	41 13	— 1 27	39 27
9	23 26	26 48	18 13	—31	42 49	— 1 33	40 20
11	21 23	23 22	18 38	—23	40 37	— 1 34	39 17
12	23 2	26 6	18 40	—16	42 58	— 1 34	38 46
				Mean	145 38 56		145 39 8
1	248 57 30	58 56	19 56	—10	159 17 59	+ 0 16	159 18 49
2	55 48	56 46	21 45	—12	17 50	+ 0 16	19 13
3	58 18	59 38	20 19	—13	19 4	+ 0 16	18 59
4	59 18	00 35	18 22	—13	18 5	+ 0 14	18 48
5	57 0	58 55	20 8	—13	17 53	+ 0 14	19 10
7	249 00 7	1 32	18 37	—17	19 9	— 0 54	19 18
8	1 15	2 5	18 54	— 8	20 26	— 0 54	19 13
9	2 18	4 18	18 13	—27	21 4	— 0 58	19 10
11	1 18	2 45	18 38	—18	20 22	— 0 58	19 38
12	2 55	4 58	18 40	—10	22 26	— 0 58	18 50
				Mean	159 19 26		159 19 7

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.				
26 (29)	1	.9975	.0135	183	—15	114	.0330	— 5	—.0091	49.0234
	2	.0162	.0226	207	—15	114	.0492	+13	—.0091	.0414
	3	.0286	.0154	242	—15	114	.0553	+ 2	—.0091	.0464
	4	.0159	.0140	220	—18	121	.0464	+56	—.0075	.0445
	5	.0173	.9999	259	—18	120	.0439	+ 9	—.0075	.0373
	6	.0185	.0212	309	—18	110	.0591	—25	—.0075	.0491
	7	.9586	.9565	221	+21	114	.9923	— 3	+.0299	.0219
	8	.9839	.9789	203	+21	114	.0144	+ 3	+.0299	.0446
	11	.9594	.9571	228	+25	124	.9951	—18	+.0322	.0255
	12	.9566	.9410	209	+25	120	.9834	—21	+.0322	.0135
						Mean				49.0348
27 (20)	12	.8166	.8112	298	+45	132	.8570	—38	+.0144	89.8676
28 (24)	4	.7395	.7356	265	—23	117	.7720	+72	—.0056	62.7736
	6	.7193	.7225	269	—23	114	.7554	—32	—.0056	.7466
	11	.7391	.7261	285	+31	114	.7741	—23	+.0241	.7959
	12	.6891	.6803	243	+31	113	.7219	—26	+.0241	.7434
						Mean				62.7649
29 (28)	1	.0709	.0682	200	—15	110	.0982	— 5	—.0094	51.0883
	2	.0724	.0725	227	—15	110	.1038	+14	—.0094	.0958
	3	.0856	.0750	264	—15	110	.1154	+ 2	—.0094	.1062
	4	.0794	.0760	242	—19	117	.1109	+59	—.0078	.1090
	5	.0785	.0611	280	—19	114	.1065	+ 9	—.0078	.0996
	6	.0877	.0677	329	—19	110	.1189	—26	—.0078	.1085
	7	.9937	.9865	246	+22	115	.0276	— 3	+.0309	.0582
	8	.0371	.0175	219	+22	113	.0619	+ 3	+.0309	.0931
	11	.0104	.0034	254	+26	110	.0451	—19	+.0333	.0765
	12	.0354	.0176	228	+26	113	.0624	—22	+.0333	.0935
						Mean				51.0929
30 (30)	4	.5448	.5838	259	—22	110	.5977	+69	—.0072	59.5974
31 (23)	1	.4623	.4634	307	—24	137	.5014	— 8	—.0053	82.4953
	2	.4626	.4558	314	—24	137	.4984	+22	—.0053	.4953
	3	.4533	.4532	318	—24	137	.4928	+ 3	—.0053	.4878
	4	.4606	.4474	318	—30	136	.4929	+95	—.0044	.4980
	5	.4502	.4638	318	—30	140	.4963	+15	—.0044	.4934
	6	.4646	.4577	316	—30	137	.5000	—42	—.0044	.4914
	7	.4279	.4294	327	+36	141	.4756	— 6	+ 0173	.4923
	8	.4457	.4360	279	+36	138	.4826	+ 6	+.0173	.5005
	9	.4184	.4200	386	+41	136	.4720	—32	+.0186	.4874
	10	.4276	.4293	323	+41	140	.4754	+ 12	+.0186	.4952
	11	.4321	.4333	336	+41	137	.4806	—31	+.0187	.4962
	12	.4344	.4208	290	+41	140	.4712	—35	+.0187	.4864
						Mean				82.4933

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac	Corrected. Mean. *p*	Proper Motion.	Final Corrected Angle. π
1	156° 31′ 26″	34′ 24″	19′ 56″	+10″	66° 53′ 1″	— 0′ 10″	66° 53′ 25″
2	29 3	30 55	21 45	+13	51 57	— 0 10	52 54
3	31 42	33 17	20 19	+15	53 5	— 0 10	52 34
4	33 38	35 55	18 22	+14	53 23	— 0 9	53 43
5	31 1	32 35	20 8	+14	52 10	— 0 9	53 4
6	31 5	32 18	14 4	+15	46 1	— 0 9	52 59
7	31 20	30 45	18 37	+18	49 58	+ 0 34	51 35
8	30 52	31 58	18 54	+ 9	50 28	+ 0 34	50 43
11	32 25	34 26	18 38	+19	52 23	+ 0 37	53 14
12	33 13	35 15	18 40	+13	53 7	+ 0 37	51 6
				Mean	66 51 33		66 52 32
12	236 48 54	50 17	18 40	—15	147 8 1	— 1 11	147 4 12
4	216 8 8	10 18	18 22	—17	126 27 18	+ 0 18	126 28 5
6	6 47	8 0	14 4	—35	20 53	+ 0 18	28 18
11	9 50	13 3	18 38	—21	29 43	— 1 18	28 39
12	11 12	14 53	18 40	—16	31 26	— 1 18	27 30
				Mean	126 27 20		126 28 8
1	168 36 24	38 27	19 56	+ 8	78 57 29	— 0 2	78 58 1
2	33 52	35 5	21 45	+ 8	56 21	— 0 2	57 26
3	36 8	38 8	20 19	+ 7	57 34	— 0 2	57 11
4	38 28	38 36	18 22	+ 8	57 2	— 0 2	57 29
5	35 23	37 50	20 8	+ 5	56 49	— 0 2	57 50
6	36 16	36 30	14 4	— 1	50 26	— 0 2	57 31
7	37 2	36 42	18 37	+10	55 39	+ 0 7	56 49
8	38 30	38 32	18 54	+ 3	57 28	+ 0 7	57 16
11	39 16	39 55	18 38	+13	58 27	+ 0 7	58 48
12	39 38	42 6	18 40	+ 5	59 37	+ 0 7	57 6
				Mean	78 56 41		78 57 33
4	150 3 18	5 32	18 22	+16	60 23 3	— 0 10	60 23 22
1	228 14 25	15 55	19 56	— 11	138 34 55	+ 0 20	138 35 49
2	12 0	13 53	21 45	—16	34 26	+ 0 20	35 53
3	15 42	16 5	20 19	—22	35 50	+ 0 20	35 49
4	16 0	17 28	18 22	—19	34 47	+ 0 16	35 32
5	14 8	15 30	20 8	—24	34 33	+ 0 16	35 52
6	13 55	14 50	14 4	—31	27 55	+ 0 16	35 18
7	17 7	18 8	18 37	—22	35 53	— 1 6	35 50
8	18 3	19 36	18 54	—14	37 30	— 1 6	36 5
9	19 25	21 48	18 13	—30	38 19	— 1 10	36 13
10	20 45	21 43	16 30	—23	37 21	— 1 10	35 56
11	18 52	19 5	18 38	—24	37 13	— 1 11	36 16
12	19 38	22 5	18 40	—17	39 15	— 1 11	35 26
				Mean	138 35 40		138 35 50

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Concluded.*)

Star No.	Plate.	Observed Dist		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	*s*			σ
32	1	.2646	.2658	344	—32	120	.3005	— 10	—.0062	109.2933
(32)	2	.2655	.2600	368	—32	138	.3014	+ 29	—.0062	.2981
	4	.2768	.2702	384	—40	128	.3128	+125	—.0052	.3201
	7	.2306	.2495	364	+48	130	.2863	— 7	+.0205	.3061
	8	.2388	.2309	368	+48	130	.2815	+ 7	+.0205	.3027
	9	.2557	.2180	349	+54	139	.2831	— 43	+.0219	.3007
	10	.2360	.2386	355	+54	128	.2831	+ 16	+.0219	.3066
	11	.2292	.2214	368	+55	138	.2735	— 41	+.0221	.2915
	12	.2333	.2124	370	+55	118	.2693	— 46	+.0221	.2868
						Mean				109.3007
33	1	.0454	.0412	321	—28	140	.0812	— 9	—.0078	95.0725
(31)	2	.0511	.0403	357	—28	144	.0876	+ 25	—.0078	.0823
	3	.0424	.0366	412	—28	140	.0865	+ 4	—.0078	.0791
	4	.0404	.0354	377	—34	144	.0812	+109	—.0064	.0857
	5	.0409	.0282	441	—34	144	.0843	+ 17	—.0064	.0796
	6	.0380	.0428	529	—35	138	.0982	— 48	—.0064	.0870
	7	.0000	.9866	366	+42	143	.0430	— 6	+.0256	.0680
	8	.0001	.9929	356	+42	142	.0451	+ 6	+.0256	.0713
	9	.0036	.9918	366	+47	140	.0476	— 37	+.0274	.0713
	10	.9968	.0042	360	+47	143	.0500	+ 14	+.0274	.0788
	11	.9996	.9859	373	+48	143	.0388	— 35	+.0276	.0629
	12	.0000	.9922	364	+48	144	.0463	— 40	+.0276	.0699
						Mean				95.0757
34	7	.9473	.9391	472	+54	118	.9957	— 8	+.0158	124.0107
(19)	8	.9583	.9454	410	+54	118	.9981	+ 8	+.0158	.0147
	11	.9655	.9507	490	+62	108	.0122	— 46	+.0171	.0247
	12	.9702	.9496	427	+62	113	.0082	— 52	+.0171	.0201
						Mean				124.0175
35	10	.5560	.5567	516	+57	119	.6164	+ 17	+.0251	114.6432
(27)	11	.5637	.5550	535	+58	114	.6209	— 43	+.0253	.6419
						Mean				.6426

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Concluded.*)

Plate.	Observed Position Angle. East.	 West.	Zero Correction plus precession, etc	Refrac.	Corrected Mean. *p*	Proper Motion.	Final Corrected Angle π
	° ′ ″	′ ″	′ ″	″	° ′ ″	′ ″	° ′ ″
1	123 33 26	35 6	19 56	+ 7	33 54 19	— 0 13	33 54 40
2	31 20	32 52	21 45	+14	54 5	— 0 13	54 59
4	35 45	37 38	18 22	+16	55 20	— 0 11	55 38
7	33 42	34 58	18 37	+18	53 15	+ 0 43	55 1
8	34 55	35 55	18 54	+14	54 33	+ 0 43	54 57
9	35 42	37 33	18 13	+22	55 13	+ 0 46	55 3
10	37 3	38 19	16 30	+19	54 30	+ 0 46	55 1
11	35 10	35 40	18 38	+19	54 22	+ 0 46	55 22
12	37 10	38 13	18 40	+16	56 38	+ 0 46	54 46
				Mean	33 54 42		33 55 3
1	137 57 13	58 37	19 56	+10	48 18 1	— 0 11	48 18 24
2	54 50	56 2	21 45	+16	17 27	— 0 11	18 23
3	57 53	58 23	20 19	+22	18 49	— 0 11	18 17
4	58 37	00 23	18 22	+19	18 11	— 0 9	18 31
5	56 2	57 58	20 8	+24	17 32	— 0 9	18 26
6	56 15	57 18	14 4	+31	11 21	— 0 9	18 19
7	56 45	57 41	18 37	+22	16 12	+ 0 37	17 52
8	57 38	59 4	18 54	+14	17 29	+ 0 37	17 47
9	58 53	00 58	18 13	+30	18 39	+ 0 39	18 22
10	138 00 7	1 45	16 30	+23	17 49	+ 0 39	18 13
11	137 57 36	58 55	18 38	+24	17 18	+ 0 40	18 12
12	138 00 23	2 5	18 40	+17	20 11	+ 0 40	18 13
					48 17 25		48 18 15
7	231 32 22	33 3	18 37	—22	141 50 57	— 0 46	141 51 14
8	33 2	34 40	18 54	—14	52 32	— 0 46	51 27
11	33 8	34 38	18 38	—24	52 7	— 0 49	51 32
12	34 47	37 13	18 40	—16	54 24	— 0 49	50 57
				Mean	141 52 30		141 51 18
10	213 4 38	6 18	16 30	—19	123 21 39	— 0 41	123 20 43
11	2 32	3 35	18 38	—20	21 21	— 0 41	20 54
				Mean	123 21 30		123 20 48

TABLE VII.—FOR PROPER MOTION, ETC.

Plate No.	$t-1874$ τ	P_1	P_6	P'	Correction for Variation.	
					Scale × 10^3	Orientation.
				″		′ ″
1	—0.127	—.0094	—1942.6	+0.4	—.00957	+0 34
2	— .127	—.0094	—1942.6	+0.4	+.02660	+1 7
3	— .127	—.0094	—1942.6	+0.4	+.00373	—0 21
4	— .105	—.0078	—1606.2	+0.3	+.11455	+0 29
5	— .105	—.0078	—1606.2	+0.3	+.01820	+1 3
6	— .105	—.0078	—1606.2	+0.3	—.05086	+7 7
7	+ .418	+.0310	+6394.2	—1.3	—.00677	+1 3
8	+ .418	+.0310	+6394.2	—1.3	+.00677	—0 19
9	+ .448	+.0332	+6852.9	—1.4	—.03896	—0 56
10	+ .448	+.0332	+6852.9	—1.4	+.01446	—0 15
11	+ .451	+.0334	+6898.7	—1.4	—.03733	+0 14
12	+ .451	+.0334	+6898.7	—1.4	—.04223	—2 38

TABLE VIII.—FOR PROPER MOTION.

Star No.	In Distance.	In Position Angle.		
	S_1	S_5	S_6	S_7
1	—1.000	—.0104	.0081	—.00008
2	—0.935	—.3558	.0085	—.00304
3	— .984	+.1783	.0132	+.00235
4	— .960	—.2803	.0125	—.00352
5	— .664	—.7481	.0083	—.00621
6	—0.838	—.5454	.0165	—.00899
7	— .622	—.7829	.0112	—.00875
8	— .673	+.7401	.0171	+.01265
9	— .990	+.1428	.0337	+.00482
10	— .978	—.2087	.0538	—.01122
11	—0.232	—.9727	.0094	—.00919
12	— .568	—.8231	.0826	—.06795
13	— .253	—.9676	.0416	—.04022
14	— .155	—.9879	.0126	—.01250
15				
16	—0.103	—.9947	.0125	—.01245
17	+ .280	+.9601	.0255	+.02450
18	+ .563	+.8263	.0352	+.02911
19	+ .137	—.9906	.0179	—.01769
20	+ .349	+.9370	.0112	+.01047
21	+0.630	—.7768	.0312	—.02424
22	+ .130	—.9915	.0098	—.00970
23	+ .174	—.9847	.0080	—.00791
24	+ .453	—.8916	.0150	—.01339
25	+ .229	—.9734	.0084	—.00821
26	+0.963	+.2709	.0204	+.00553
27	+ .430	—.9030	.0111	—.01005
28	+ .721	—.6932	.0159	—.01104
29	+ .998	+.0633	.0196	+.00124
30	+ .926	+.3777	.0168	+.00634
31	+0.559	—.8292	.0121	—.01005
32	+ .661	+.7508	.0092	+.00687
33	+ .826	+.5636	.0105	+.00593
34	+ .510	—.8599	.0081	—.00693
35	+ .757	—.6532	.0087	—.00570

TABLE IX.—MEAN RESULTS.

Star No.	Distance.	Position Angle.			$\alpha'-\alpha$	$\delta'-\delta$	No. of Plates.	Durchmusterung.	
								No.	Mag.
	″	°	′	″	″	″		°	
1	3471.54	261	57	38	—6200.11	— 528.57	2	56.2942	9.4
2	3279.96	241	44	1	—5170.81	—1583.43	8	55.2898	9.1
3	2125.81	272	51	16	—3846.67	+ 89.36	12	56.2952	7.5
4	2233.14	246	18	15	—3677.83	— 912.64	12	56.2953	8.6
5	3376.37	214	9	24	—3363.40	—2806.80	5	55.2908	9.3
6	1699.59	229	30	18	—2321.22	—1109.73	5	56.2956	8.5
7	2505.96	211	2	20	—2303.23	—2153.15	8		
8	1639.11	310	19	51	—2279.93	+1055.07	12	56.2958	7.0
9	830.27	270	47	43	—1503.17	+ 9.01	12	56.2961	9.0
10	521.11	250	31	59	— 888.41	— 174.55	12	56.2962	9.0
11	2964.74	185	59	15	— 548.13	—2948.90	12	55.2915	9.3
12	339.10	207	10	5	— 279.71	— 301.78	4	56.2963	8.7
13	673.84	187	11	15	— 151.89	— 668.58	12	56.2964	9.1
14	2213.72	181	29	16	— 102.40	—2212.98	12	55.2917	8.2
15			*Bradley*		*3077*			56.2966	6.0
16	2237.48	178	30	17	+ 104.00	—2236.73	12	55.2919	7.6
17	1097.56	8	50	15	+ 307.73	+1084.43	12	56.2969	8.0
18	795.11	26	52	45	+ 654.24	+ 708.74	6	56.2970	9.1
19	1568.18	164	42	34	+ 740.56	—1513.29	12	55.2920	9.3
20	2508.31	13	2	27	+1043.41	+2442.43	12	57.2712	8.0
21	897.34	133	31	53	+1172.55	— 619.58	9	56.2972	9.3
22	2865.34	165	3	17	+1311.41	—2770.35	3	55.2922	9.5
23	3490.36	162	32	2	+1851.74	—3333.34	10	55.2925	8.5
24	1864.76	145	39	8	+1883.65	—1543.60	11	55.2926	8.5
25	3321.66	159	19	7	+2076.84	--3112.52	10	55.2928	8.3
26	1373.58	66	52	32	+2296.06	+ 533.57	10	56.2974	9.4
27	2517.41	147	4	12	+2439.97	—2119.69	1		
28	1758.20	126	28	8	+2540.40	—1052.30	4		
29	1431.23	78	57	33	+2548.30	+ 266.85	10	56.2975	9.4
30	1669.47	60	23	22	+2643.71	+ 817.13	1	56.2976	9.5
31	2310.84	138	35	50	+2732.23	—1741.73	12	55.2929	7.6
32	3061.77	33	55	3	+3151.75	+2529.88	9	57.2715	8.5
33	2663.30	48	18	15	+3647.57	+1756.88	12	56.2978	7.0
34	3474.03	141	51	18	+3808.68	—2748.62	4	55.2933	8.9
35	3211.41	123	20	48	+4794.57	—1791.25	2	55.2935	9.4

TABLE X.—CATALOGUE OF STARS.

Star No.	Helsingfors-Gotha No.	Right Ascension, 1874.	Precession, *J*	Sec. Var., *K*	Declination, 1874.	Precession, *L*	Sec Var. *M*
		h m s	s	s	° ′ ″	″	″
1		23 0 20.015	+2.5557	+.0276	56 19 33.38	+19.378	+.088
2	13747	1 28 635	2.5709	.0279	56 1 58.52	19.404	.086
3	13768	2 56.911	2.5746	.0286	56 29 51.31	19.436	.084
4	13773	3 8.167	2.5814	.0285	56 13 9.31	19.440	.084
5		3 29.129	2.5939	.0283	55 41 35.15	19.447	.084
6	13801	4 38.608	+2.5952	+.0289	56 9 52.22	+19.472	+.082
7		4 39.807	2.6004	.0288	55 52 28.80	19.473	.083
8	13805	4 41.361	2.5846	.0293	56 45 57.02	19.473	.082
9	13814	5 33.145	2 5973	.0294	56 28 30 96	19.491	.081
10	13826	6 14.129	2.6041	.0296	56 25 27.40	19 505	.080
11	13829	6 36.814	+2.6206	+.0292	55 39 13.05	+19.513	+.080
12	13836	6 54.709	2.6105	.0298	56 23 20.17	19.519	.079
13	13837	7 3.230	2.6134	.0298	56 17 13.37	19.522	.079
14	13839	7 6.529	2.6213	.0295	55 51 28.97	19 523	.079
15	**13841**	**23 7 13.356**	**2.6116**	**.0300**	**56 28 21.95**	**19.525**	**.078**
16	13844	7 20.289	+2 6233	+.0296	55 51 5.22	+19.527	+.079
17	13848	7 33 871	2.6093	.0303	56 46 26.38	19.532	.078
18	13850	7 56.972	2.6145	.0303	56 40 10.69	19.539	.077
19	13852	8 2.727	2.6259	.0299	56 3 8 66	19.541	.078
20	13856	8 22.917	2.6098	.0308	57 9 4.38	19 548	.077
21		8 31.526	+2 6255	+.0303	56 18 2 37	+19.551	+.077
22		8 40.783	2.6369	.0303	55 42 11.60	19.554	.077
23	13870	9 16.805	2.6445	.0300	55 32 48.61	19.565	.076
24	13871	9 18.933	2.6367	.0303	56 2 38 35	19.566	.076
25	13875	9 31.812	2.6454	.0301	55 36 29.43	19.570	.076
26		9 46.427	+2.6310	+.0308	56 37 15.52	+19 575	+.074
27		9 56.021	2.6445	.0304	55 53 2.26	19.578	.076
28		10 2.716	2.6407	.0304	56 10 49.65	19.580	.076
29		10 3.243	2.6347	.0304	56 32 48.80	19.580	.076
30		10 9.603	2.6332	.0304	56 41 59.08	19 582	.076
31	13885	10 15.505	+2.6455	+.0306	55 59 20.22	+19.584	+.075
32	13894	10 43.473	2.6300	.0316	57 10 31.83	19 593	.073
33	13903	11 16.527	2.6385	.0316	56 57 38.83	19.603	.073
34	13907	11 27.268	2.6600	.0308	55 42 33.33	19.606	.073
35		12 32.994	2.6652	.0313	55 58 30.70	19 626	.071

VI.—*The Præsepe Group; Measurement and Reduction of the Rutherfurd Photographs.*

By Frank Schlesinger.

Read April 4, 1898.

I.

Description of the Plates.

The collection of astronomical photographs presented by the late Lewis M. Rutherfurd to the Observatory of Columbia University contains eleven photographs of Præsepe taken with his larger and improved instrument; only eight of these were measured and reduced, three having been judged inferior to the rest. According to Rutherfurd's invariable practice, each plate shows two complete pictures of the group separated by about a millimetre in right ascension, the driving clock of the instrument having been stopped for a few seconds after the completion of the first or eastern impression. Near the west edge of the plate still a third image of each of the brighter stars in the group is found, separated by about forty millimetres from the two other impressions, the driving clock having been stopped for an interval of about three minutes after the completion of the second impression, and then started again and allowed to run long enough to permit the brighter stars to leave well-defined images. The object in securing these third impressions or *trails* was to afford means for orienting the group, but in the present work they were not used for this purpose, the orientation having been effected in another way. It is important, however, to know how accurately the use of trails will give the orientation, and they were therefore completely measured and reduced, and the results compared with those obtained by the method actually employed, which is of unquestioned accuracy but may not be always available.

A perpendicular to the plate passing through the optical centre of the object glass pierces the plate at a point whose approximate position must be known in order to reduce the measures of the stars to right ascensions and declinations. Rutherfurd so adjusted his plate holder that this point coincides approximately with the image of the central star of the group, numbered 15 in the following pages.

Table I gives the data of exposure for the plates. Plates VI, X and XI do not appear, these being the ones that were not measured, on account of their inferiority. This is due to the fact that the photographic images of the stars on these plates, when viewed under the microscope of the measuring machine were neither so round nor so well defined as on the other plates and therefore did not admit of so accurate measurement. The irregularity of the images is not due to a deterioration of the plates since they were taken, but to the bad behavior of RUTHERFURD's clock during the exposures. For this reason these three plates were never measured, it being deemed probable that more reliable results are to be obtained from the eight plates actually reduced, than if all the plates had been measured, in spite of the greater number of observations in the latter case. In this connection I should also say that not all the stars which appear on the plates were measured. A few whose images come near the edges of the plates were rejected, for not only are these images much distorted, but as we shall see later, the corrections become uncertain as we recede from the centre of the plate.

TABLE I.—PHOTOGRAPHS OF PRÆSEPE.

Observatory of L. M. Rutherfurd, New York.

Lat. = 40°43′48″.5 Long. = $4^h55^m56^s.62$ W.

No.	Date.	Sidereal Time.	Bar	Thermometers.			Focus
				Att.	Ext.	Tel.	
		h m s		°	°	°	
I	1870 Apr. 24	10 45 05	30.01	60	55	58	8.4
II	1870 Apr. 24	11 25 35	30.01	60	55	58	8.4
III	1870 Apr. 25	11 10 35	30.26	53	47	53	8.4
IV	1870 Apr. 25	11 59 35	30.26	53	47	53	8.4
V	1877 Apr. 14	10 39 38	30.06	47	45	48	7.8
VII	1877 Apr. 25	11 26 02	30.06	57	56	58	7.7
VIII	1877 Apr. 25	11 53 32	30.06	57	56	58	7.7
IX	1877 May 2	10 57 08	29.86	47	46	48	7.8

The column marked "sidereal time" gives the mean of four instants for each plate: beginning of east exposure, end of east exposure, beginning of west exposure and end of west exposure; each exposure lasted six minutes. Three thermometers were read: attached, external and telescope, the last being in contact with the telescope-tube. The last column, marked " focus," gives the reading of a micrometer head attached to the eye end of the telescope and shows the position of the plate holder; this information is not used in the reductions and is given only to provide for the possibility of determining a relation between this reading and the scale-value after a sufficient number of the photographs made with this instrument has been reduced.

II.

Measurement of the Plates.

The plates were measured with the older Repsold Measuring Machine of this Observatory, which is a counterpart of the one by the same maker belonging to the University of Leyden except that an alteration has been made which obviates "projection errors." (See III.) A full description of the Leyden machine is given in the "Bulletin du Comité Permanent," Vol. 1, page 169, and also in the recent work by Dr. Scheiner, "Photographie der Gestirne," page 148. The machine is so constructed that the position of a star may be determined either by position angle and distance or by rectangular coördinates; the latter method was adopted in the present case. A star which is to be measured may be brought into the field of the reading microscope by moving the plate along a straight guiding cylinder and then moving the microscope at right angles to the cylinder on another straight guiding way. The wire of the micrometer is made to bisect the image of the star and the micrometer head is read. Then the whole microscope is revolved through a small vertical angle and the wire set upon a scale of millimetres placed parallel to the motion of the microscope. The difference of the two readings on star and scale, together with the number of the line on the scale gives us the position of the star. Having gone through the same operation for all the stars we obtain their relative positions, at least in one direction; the plate is now revolved through 90° by means of the graduated circle and the stars are again measured; these two sets of measures are sufficient to fix the relative positions of the stars, but in order to secure greater accuracy and especially to eliminate personality the plate is turned 180° and 270° respectively from its original position, and the stars are read a third and a fourth time. By means of the trails or otherwise the plate may be so placed in the machine that a circle of declination through the central star shall be approximately parallel to the guiding cylinder; in this way we obtain rectangular coördinates which are nearly in the directions of right ascensions and declinations, thus rendering their conversion into the latter a comparatively easy matter.

Two observers alternated in the measurements, one recording while the other observed; the details of each morning's work, which usually lasted a little over two hours, are as follows: the first observer reads the circle, runs and temperature, the second reads on the central star thus: East image, scale, scale, east image; west image, scale, scale, west image. Continuing, the second observer goes through the same operations for usually three other stars, experience having shown that four stars could be read conveniently without fatiguing the eye; thus the observers alternate till twenty or twenty-five stars have been read and then the temperature is recorded a second time. The morning's work is now half finished; the same stars are then observed in the reverse order, care being taken that each observer shall now read those stars that he had not read in the first half; having finally gotten back to the central star, temperature, runs and the circle are read as at the beginning. This process of repeating all the measurements in the reverse order, eliminates the effects of any change in the machine or in the observers that is proportionate to the time, for the mean of the two times of observation is nearly the same for all the stars. In the first half of the morning's work the micrometer head is set at about $9.^{R}0$ when pointed at a star; but in the second half the reading is made $9.^{R}5$; in this way periodic errors of the screw are nearly eliminated, for both star and scale are read with two different parts of the screw separated by half a turn.

The measurements made in the first position of the plate, *i. e.*, with the stars having the greatest *right ascensions* farthest from the cylinder are recorded as "x direct;" on the next day the plate is turned 90° in a counter-clockwise direction so that now the stars having the greatest *north polar distances* are farthest from the cylinder. The measurements taken in this position are called "y direct," while those taken in the two opposite positions, 180° and 270° from the original position are called respectively "x reversed" and "y reversed." As only twenty or twenty-five stars could be measured on each day, and as the photographs of Præsepe show about forty-five stars that admit of measurement, it was necessary to spend two days on each position of the plate. To eliminate the effect of a possible motion of the plate or of the scale the central star 15 was read each day by both observers. After three of the plates had been measured, viz.: III, VII and IX, it was decided to read the central star more often, so that on the succeeding plates four such readings were made every day, instead of two.

Three observers were engaged in the measurement of the first five plates, but only two were concerned in the work for any single day. Care was always taken to have the same pair of observers make both the direct and the reversed measurements of a particular set of stars, in order to eliminate personality. Suppose one of the observers has contracted the habit of always setting the micrometer wire too far to the right of the centre of a star's image by an amount depending upon the size of the image; the distance between two stars as obtained by such an observer will be subject to an error which depends upon the difference of magnitudes of the stars. But when the plate is reversed 180°, the same observer will get a distance which is too small by as much as the first distance was too large or vice versa; consequently the mean of the two measurements will be free from such personality as we have supposed. However, this method of measurement does not eliminate all personality, for the star images are seldom round and are usually more sharply defined on one edge than upon the other; two observers will thus sometimes differ considerably in their estimations of the true centre of the image.

Table II gives the runs, circle reading, etc., for each day. Runs were observed twice daily, once before and once after the measurement of the stars; the number in the column headed "runs" is the mean of the two determinations expressed in millimetres. The circle was also read twice, employing two microscopes 180° apart for each reading; in the column marked "circle" the degrees and minutes are always taken from the right-hand microscope, while the number of seconds is the mean of both microscopes. The thermometer occupied a fixed position near the plate and was graduated in Fahrenheit degrees. The last column gives the initials of the three observers, Kretz, Hays and Schlesinger.

TABLE II.—DAILY RECORDS.

Date, 1897.	Runs in mm.	Circle.	Ther.	Position of Plate, and Stars Measured.	Obs'rs.
Plate III.					
Jan. 12	—0.0029	185° 58′ 00″	63.3	x direct; 2-4, 6, 8, 10, 11, 14-18, 20, 22-24, 26, 28, 29, 45.	S, K
" 13	—0.0026	275 57 57	67.0	y direct; 2-4, 6, 8, 10, 11, 14-18, 20, 22-26, 28, 29, 33.	S, H
" 18	—0.0026	5 58 00	63.2	x reversed; see Jan. 12.	S, K
" 19	—0.0021	185 57 57	60.8	x direct; 1, 2, 5, 7, 15, 23A, 25, 27, 31-37; 39, 40, 43-45.	K, H
" 20	—0.0016	95 58 02	63.6	y reversed; see Jan. 13.	S, H
" 21	—0.0025	275 58 01	65.2	y direct; 1, 5, 7, 15, 23A, 27, 31-37, 39, 40, 43-45.	S, H
" 23	—0.0035	5 58 00	60.5	x reversed; see Jan. 19.	K, H
" 26		275 58 00		Trails; 15, 23, 27, 31.	S, K
" 27	—0.0020	95 58 00	61.6	y reversed; see Jan. 21.	S, H
Plate IX.					
Feb. 5	+0.0028	177° 37′ 02″	63.2	x direct; 2-4, 6, 8, 10, 11, 14-18, 20, 22-29, 45.	S, K
" 8		267 37 01		Trails; 15, 23, 31, 37.	S, K
" 9	+0.0016	267 37 00	62.2	y direct; 2-4, 6, 8, 10, 11, 14-18, 20, 22-29, 33.	K, H
" 10	+0.0010	267 36 58	63.6	y direct; 1, 5, 7, 15, 23A, 31-40, 43-45.	S, H
" 11	+0.0021	87 37 02	60 9	y reversed; see Feb. 10.	S, H
" 13	+0.0006	87 37 01	63.5	y reversed; see Feb. 9.	K, H
" 16	+0.0031	357 37 02	64.2	x reversed; see Feb. 19.	K, H
" 17	—0.0016	357 37 00	65.9	x reversed; see Feb. 5.	S, K
" 19	+0.0036	177 37 02	66.4	x direct; 1, 2, 5, 7, 15, 23A, 31-40, 43-45.	K, H
Plate VII.					
Feb. 26	+0.0026	86° 54′ 00″	63 8	x direct; 2-4, 6, 8, 10, 11, 14-18, 20, 22-29, 31-33, 45.	S, H
" 27	+0.0030	356 54 00	62.1	y reversed; see Mar. 1.	S, K
Mar. 1	+0.0039	176 54 02	59.4	y direct; 2-4, 6, 8, 10, 11, 14-18, 20, 22-29, 31-33.	S, K
" 2	+0.0011	176 54 02	65.1	y direct; 1, 5, 7, 7A, 15, 19, 21, 23A, 33-45.	K, H
" 3	+0.0039	86 53 58	65.9	x direct; 1, 2, 5, 7, 7A, 15, 19, 21, 23A, 34-45	S, H
" 4	+0.0044	266 53 56	66.8	x reversed; see Feb. 26.	S, H
" 5		176 54 00		Trails; 15, 22, 23, 31.	S, H
" 6	+0.0045	356 54 03	65.8	y reversed; see Mar. 2.	K, H
" 8	+0.0026	266 54 00	60.8	x reversed; see Mar. 3.	S, H

TABLE II.—DAILY RECORDS. (*Continued.*)

Date, 1897.	Runs in mm.	Circle.	Ther.	Position of Plate, and Stars Measured.	Obsr's.
				Plate VIII.	
Mar. 15	+0.0036	177° 02′ 28″	56.8	*x* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 31, 45.	S, K
“ 16	+0.0036	267 02 30	62.6	*y* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22, 29, 31, 33.	K, H
“ 17	+0.0039	357 02 31	60.4	*x* reversed; see Mar. 15.	S, K
“ 18	+0.0036	357 02 27	62.3	*x* reversed; see Mar. 25.	S, H
“ 20	+0.0050	87 02 32	62.0	*y* reversed; see Mar. 16.	K, H
“ 22	+0.0045	87 02 28	64.6	*y* reversed; see Mar. 24.	S, K
“ 23		267 02 29		Trails; 15, 22, 23, 31.	K, H
“ 24	+0.0042	267 02 34	63.9	*y* direct; 1, 5, 7, 7A, 15, 19, 23A, 32–45.	S, K
“ 25	+0.0045	177 02 29	62.8	*x* direct; 1, 2, 5, 7, 7A, 15, 19, 23A, 32–45.	S, H
				Plate II.	
Apr. 3	+0.0015	276° 00′ 00″	65.9	*y* direct; 2, 4, 6, 8, 10, 11, 14–18, 20, 22–26, 28, 29, 33.	K, H
“ 5	+0.0015	185 59 59	65.9	*x* direct; 2, 4, 6, 8, 10, 11, 14–18, 20, 22–29, 45.	S, K
“ 6	+0.0001	96 00 02	67.8	*y* reversed; see Apr. 3.	K, H
“ 7	+0.0018	6 00 00	67.8	*x* reversed; see Apr. 5.	S, K
“ 8	+0.0035	6 00 00	67.6	*x* reversed; see Apr. 10.	S, H
“ 9	+0.0046	276 00 00	64.7	*y* direct; 1, 5, 7, 7A, 15, 19, 23A, 27, 31–40, 43–45.	K, H
“ 10	+0.0055	185 59 58	65.6	*x* direct; 1, 2, 5, 7, 7A, 15, 19, 23A, 31–40, 43–45.	S, H
“ 14	+0.0062	95 59 59	65.9	*y* reversed; see Apr. 9.	K, H
				Plate IV.	
Apr. 24	+0.0101	186° 16′ 58″	69.7	*x* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 45.	S, K
“ 28	+0.0109	6 17 01	65.9	*x* reversed; see Apr. 24.	S, K
“ 29	+0.0151	276 17 00	66.9	*y* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–26, 28, 29, 33.	S, K
May 1	+0.0165	96 17 02	67.5	*y* reversed; see Apr. 29.	S, K
“ 3	+0.0155	96 16 58	65.0	*y* reversed; see May 5.	S, K
“ 4	+0.0136	186 16 58	66.0	*x* direct; 1, 2, 5, 7, 7A, 15, 19, 23A, 31–40, 43–45.	S, K
“ 5	+0.0156	276 16 57	66.9	*y* direct; 1, 5, 7, 7A, 15, 19, 23A, 27, 31–40, 43–45.	S, K
“ 6	+0.0160	6 17 00	68.8	*x* reversed; see May 4.	S, K
“ 8		276 17 01		Trails; 15, 23, 31, 37.	S, K

Table II.—Daily Records. (*Concluded.*)

Date, 1897.	Runs in mm.	Circle.	Ther.	Position of Plate, and Stars Measured.	Obs'rs.
				Plate I.	
Nov. 3	—0.0080	187° 10′ 05″	65.3	*x* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29.	S, K
" 4	—0.0062	187 10 04	63.8	*x* direct; 1, 2, 5, 7, 15, 23A, 31–40, 43, 44.	S, K
" 6	—0.0076	277 10 06	65.4	*y* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 33.	S, K
" 10	—0.0056	277 10 03	65.0	*y* direct; 1, 5, 7, 15, 23A, 31–40, 43, 44.	S, K
" 11	—0.0064	7 10 07	67.0	*x* reversed; see Nov. 3.	S, K
" 13	—0.0066	7 10 05	64.1	*x* reversed; see Nov. 4.	S, K
" 16	—0.0069	97 10 05	65.2	*y* reversed; see Nov. 6.	S, K
" 17		277 10 08		Trails; 15, 23, 31, 37.	S, K
" 18	—0.0065	97 10 05	64.6	*y* reversed; see Nov. 10.	S, K
				Plate V.	
Nov. 20	—0.0041	176° 09′ 07″	64.5	*x* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 45.	S, K
" 23	—0.0060	176 09 07	64.2	*x* direct; 1, 2, 5, 7, 15, 19, 23A, 31, 32, 34, 35, 37, 39, 40, 43–45.	S, K
" 24	—0.0061	266 09 07	68.7	*y* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29.	S, K
" 26	—0.0059	266 09 06	71.0	*y* direct; 1, 5, 7, 15, 19, 23A, 31, 32, 34, 35, 37, 39, 40, 43–45.	S, K
" 27	—0.0068	356 09 07	68.5	*x* reversed; see Nov. 20.	S, K
" 30	—0.0072	356 09 04	63.4	*x* reversed; see Nov. 23.	S, K
Dec. 1	—0.0065	86 09 07	66.1	*y* reversed; see Nov. 24.	S, K
" 2	—0.0058	86 09 08	65.4	*y* reversed; see Nov. 26.	S, K

On the next page is given a specimen of the recording sheets; all the measurements relating to the same star for any one plate are recorded on one sheet. The forms are not designed for the separate reduction of the two impressions of a group which appear on each plate, but the mean of the measurements on the two images of a star is taken at once; that is, each star is treated as though it occupied the middle point between its two images. The place of this point is known when we have given the lines of the scale used in the measurement and the quantity $\frac{1}{2}m$, which is obtained thus: from the reading on the scale we subtract the reading on the star, and the mean of these differences for both images is taken, giving "Mean of Diff's;" as the scale is one of millimetres and as *two* complete turns of the screw correspond to a space on the scale we divide by 2 and get $\frac{1}{2}m$. In reading on the scale it was made a rule to select the line having the next lower number; consequently the place of a star is obtained by *adding* $\frac{1}{2}m$ to the mean of the numbers of the lines used; in rare cases, however, the next higher line was employed when it came nearly opposite to a star, as on March 24; this has been indicated by affixing a minus sign to $\frac{1}{2}m$. In the y measurements the same line was always used for both images, since the latter differ only in apparent right ascension.

Table III gives the uncorrected observations; it is only necessary to set down the numbers of the lines used and $\frac{1}{2}m$, for these not only fix the place of the star but, as we shall see later, they are sufficient for the application of all instrumental corrections. The numbers of the stars are in the order of increasing right ascensions and are those given by Professor Schur,* excepting 7*A* and 23*A*, which do not appear in his triangulation of the group. The table gives the observations of $\frac{1}{2}m$ by both observers, followed by the difference reduced to seconds of arc in order to facilitate a comparison.

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* "Astronomische Mittheilungen der K. Sternwarte zu Göttingen," part IV.

PRÆSEPE. PLATE VIII. STAR 7.

March 25, 1897; *x* direct.

	Star. Microm.	Scale Line.	Scale Microm	
East	9.053 .050	74	10.680 .681	Diff's of Mean
Mean	9.0515		10.6805	1.6290
West	9.050 .051	76	9.280 .280	
Mean	9.0505		9.2800	0.2295

Mean of Diff's = 0.9292
½ *m* = 0.4646
Measured by Hays.
Recorded by Schl.

	Star. Microm	Scale. Line	Scale. Microm	
East	9.597 .598	74	11.229 .230	Diff's of Mean
Mean	9.5975		11.2295	1.6320
West	9.579 .574	76	9.800 .800	
Mean	9.5765		9.8000	0.2235

Mean of Diff's = 0.9278
½ *m* = 0.4639
Measured by Schl.
Recorded by Hays.

March 24, 1897, *y* direct.

	Star. Microm.	Scale Line	Scale Microm	
	9.030 030	36	9.009 010	Diff's of Mean
	9.0300		9.0095	—0.0205
	9.050 .050	36	9.009 .009	
	9.0500		9.0090	—0.0410

Mean of Diff's = —0.0308
½ *m* = —0.0154
Measured by Schl.
Recorded by Kretz.

	Star. Microm	Scale. Line.	Scale. Microm	
	9.547 .540	36	9.515 .518	Diff's of Mean
	9.5435		9.5165	—0.0270
	9.562 .560	36	9.517 .517	
	9.5610		9.5170	—0.0440

Mean of Diff's = —0.0355
½ *m* = —0.0178
Measured by Kretz.
Recorded by Schl.

March 18, 1897, *x* reversed.

	Star. Microm.	Scale. Line	Scale. Microm	
	9.024 .035	44	10.513 .512	Diff's of Mean
	9.0295		10.5125	1.4830
	9.013 .023	43	9.910 .910	
	9.0180		9.9100	0.8920

Mean of Diff's = 1.1875
½ *m* = 0.5938
Measured by Schl.
Recorded by Hays.

	Star. Microm.	Scale. Line	Scale. Microm	
	9.550 .543	44	11.021 .020	Diff's of Mean
	9.5465		11.0205	1.4740
	9.535 .535	43	10.420 .419	
	9.5350		10.4195	0.8845

Mean of Diff's = 1.1792
½ *m* = 0.5896
Measured by Hays.
Recorded by Schl.

March 22, 1897; *y* reversed.

	Star. Microm.	Scale. Line.	Scale. Microm	
	9.081 .085	83	10.214 .212	Diff's of Mean
	9.0830		10.2130	1.1300
	9.070 .069	83	10.212 .211	
	9.0695		10.2115	1.1420

Mean of Diff's = 1.1360
½ *m* = 0.5680
Measured by Schl.
Recorded by Kretz.

	Star. Microm.	Scale. Line	Scale. Microm.	
	9.555 .555	83	10.681 .684	Diff's of Mean
	9.5550		10.6825	1.1275
	9.545 .540	83	10.683 .683	
	9.5425		10.6830	1.1405

Mean of Diff's = 1.1340
½ *m* = 0.5670
Measured by Kretz.
Recorded by Schl.

TABLE III.—PLATE I: x MEASUREMENTS.

Star.	x direct.				x reversed.			
	Lines.	½ m, or Scale *minus* Star.		*S—K*	Lines.	½ m, or Scale *minus* Star.		*S—K*
		Schl.	Kretz.			Schl.	Kretz.	
15	60,61	0.9016	0.8984	+0″.19	57,58	0.6695	0.6681	+0″.07
15	60,61	0.9010	0.8994	+ .07	57,58	0.6685	0.6696	— .06
2	94,95	0.4114	0.4114	.00	24,25	0.1652	0.1635	+ .08
3	93,94	0.2961	0.2954	+ .04	25,26	0.2798	0.2782	+ .08
4	91,92	0.5395	0.5419	— .13	27,28	0.0356	0.0348	+ .04
6	78,79	0.3274	0.3290	— .08	40,41	0.2472	0.2455	+ .08
8	71,72	0.4849	0.4878	— .15	47,48	0.0884	0.0849	+ .19
10	70,71	0.5885	0.5859	+ .14	48,49	— .0174	— .0169	— .03
11	69,70	0.7241	0.7252	— .06	48,49	0.8429	0.8451	— .12
14	61,62	0.1022	0.1020	+ .01	57,58	0.4649	0.4684	— .19
16	60	0.4836	0.4858	— .12	58,59	0.5859	0.5871	— .06
17	58,59	0.5726	0.5739	— .07	60,61	— .0020	— .0006	— .07
18	57,58	0.0299	0.0321	— .12	61,62	0.5404	0.5391	+ .07
20	56,57	0.6860	0.6865	— .03	61,62	0.8866	0.8865	.00
22	54,55	0.7451	0.7494	— .23	63,64	0.8208	0.8221	— .08
23	53,54	0.3750	0.3759	— .05	65,66	0.1946	0.1944	+ .01
24	51,52	0.2446	0.2451	— .03	67,68	0.3272	0.3256	+ .08
25	50,51	0.6644	0.6640	+ .02	67,68	0.9106	0.9080	+ .13
26	50,51	0.5456	0.5480	— .13	68,69	0.0282	0.0231	+ .27
27	50,51	0.2915	0.2942	— .14	68,69	0.2752	0.2784	— .17
28	50,51	0.0596	0.0622	— .14	68,69	0.5080	0.5075	+ .03
29	49,50	0.4759	0.4772	— .07	69,70	0.0936	0.0944	— .04
15	60,61	0.9005	0.8999	+0″.02	57,58	0.6698	0.6682	+0″.08
15	60,61	0.9009	0.8990	+ .12	57,58	0.6688	0.6669	+ .10
1	95,96	0.4069	0.4066	+ .02	23,24	0.1675	0.1684	— .05
2	94,95	0.4126	0.4120	+ .03	24,25	0.1625	0.1616	+ .05
5	82,83	0.5152	0.5181	— .15	36,37	0.0534	0.0540	— .03
7	75,76	0.5840	0.5830	+ .05	43,44	— .0130	— .0164	+ .18
23A	52,53	0.3599	0.3531	+ .36	66,67	0.2135	0.2155	— .11
31	48,49	0.8738	0.8725	+ .08	69,70	0.6971	0.6972	— .01
32	47,48	— .0078	— .0088	+ .05	71,72	0.5745	0.5799	— .29
33	45,46	0.3332	0.3376	— .23	73,74	0.2350	0.2410	— .32
34	44,45	0.6959	0.7006	— .25	73,74	0.8731	0.8708	+ .13
35	42,43	0.7008	0.7029	— .12	75,76	0.8659	0.8645	+ .08
36	41,42	0.2239	0.2221	+ .09	77,78	0.3489	0.3515	— .14
37	41,42	0.0792	0.0799	— .04	77,78	0.4944	0.4919	+ .13
38	37,38	0.4668	0.4691	— .12	81,82	0.1081	0.1061	+ .10
39	36,37	0.7224	0.7174	+ .26	81,82	0.8555	0.8554	.00
40	34,35	0.8836	0.8819	+ .08	83,84	0.6880	0.6890	— .05
43	27,28	— .0094	— .0124	+ .16	91,92	0.5789	0.5781	+ .04
44	26,27	0.4574	0.4624	— .26	92,93	0.1164	0.1168	— .02

TABLE III.—PLATE I: *y* MEASUREMENTS.

	y direct.				*y* reversed.			
Star.	Line.	½ *m*, or Scale *minus* Star.		*S—K*	Line.	½ *m*, or Scale *minus* Star.		*S—K*
		Schl.	Kretz.			Schl.	Kretz.	
15	52	0.3166	0.3169	—0″.02	67	0.2538	0.2550	—0″.06
15	52	0.3140	0.3176	— .19	67	0.2551	0.2545	+ .03
2	48	0.8969	0.8979	— .06	70	0.6722	0.6735	— .07
3	34	0.3140	0.3131	+ .05	85	0.2620	0.2640	— .11
4	17	0.2278	0.2255	+ .12	102	0.3502	0.3512	— .05
6	66	0.5180	0.5181	— .01	53	0.0520	0.0530	— .05
8	67	0.2651	0.2636	+ .08	52	0.3064	0.3069	— .03
10	45	0.2985	0.2952	+ .17	74	0.2756	0.2744	+ .06
11	39	0.5589	0.5594	— .03	80	0.0149	0.0134	+ .08
14	73	0.2576	0.2595	— .10	46	0.3138	0.3102	+ .19
16	18	0.0766	0.0752	+ .07	101	0.4996	0.5044	— .25
17	36	0.1639	0.1634	+ .03	83	0.4050	0.4050	.00
18	37	0.0128	0.0138	— .05	82	0.5598	0.5579	+ .10
20	36	0.2369	0.2336	+ .17	83	0.3358	0.3385	— .14
22	68	—.0124	—.0101	— .12	51	0.5811	0.5822	— .06
23	65	0.5135	0 5144	— .05	54	0.0558	0.0571	— .07
24	35	0.6510	0.6511	— .01	83	0 9205	0.9208	— .03
25	46	0.1918	0.1918	.00	73	0.3802	0.3779	+ .12
26	23	0 2064	0.2035	+ .15	96	0.3684	0.3689	— .03
27	45	0.0530	0.0535	— .03	74	0.5215	0.5174	+ .22
28	56	0.2920	0.2919	+ .01	63	0.2778	0.2786	— .04
29	79	0.9150	0.9150	.00	39	0.6569	0.6605	— .19
33	15	0.0512	0.0539	— .14	104	0.5241	0 5222	+ .10
15	52	0.3161	0.3172	—0″.06	67	0.2540	0.2525	+0″.08
15	52	0.3174	0.3172	+ .01	67	0.2535	0.2536	— .01
1	68	0 0005	0.0006	— .01	51	0.5711	0.5720	— .05
5	81	0.2686	0.2674	+ .06	38	0.3002	0.2992	+ .05
7	33	0.2762	0.2805	— .23	86	0 2989	0.2975	+ .07
23A	67	0.1061	0.1066	— .03	52	0.4675	0.4684	— .05
31	36	0.5514	0.5510	+ .02	83	0 0161	0.0155	+ .03
32	12	0.7218	0.7219	— .01	106	0.8538	0.8489	+ .26
33	15	0.0512	0.0515	— .02	104	0.5244	0.5242	+ .01
34	48	0.4732	0.4788	— .30	71	0.0906	0.0889	+ .09
35	85	0.7528	0.7519	+ .05	33	0.8198	0.8231	— .16
36	63	0.1924	0.1936	— .06	56	0.3759	0.3762	— .02
37	39	0.0658	0.0655	+ .02	80	0.5042	0.5071	— .15
38	56	0.0759	0.0802	— .23	63	0.4912	0.4900	+ .06
39	62	0.3799	0.3780	+ .10	57	0.1916	0.1932	— .08
40	17	0.4095	0.4081	+ .07	102	0.1689	0.1674	+ .08
43	59	0.2589	0.2636	— .25	60	0.3096	0.3105	— .05
44	78	0.6826	0.6850	— .13	40	0.8895	0.8870	+ .12

TABLE III.—(*Continued.*) PLATE II: *x* MEASUREMENTS.

Star.	*x* direct.				*x* reversed.			
	Lines.	½ *m*, or Scale *minus* Star.		*S—K*	Lines.	½ *m*, or Scale *minus* Star.		*S—K*
		Schl.	Kretz.	″		Schl.	Kretz.	″
15	63,64	0.7105	0.7096	+0.05	54,55	0.8424	0.8400	+0.12
15	63,64	0.7085	0.7099	— .07	54,55	0.8422	0.8426	— .02
2	97,98	0.2185	0.2192	— .04	21,22	0.3390	0.3380	+ .05
4	94,95	0.3538	0.3585	— .25	24,25	0.2039	0.1984	+ .29
6	81,82	0.1314	0.1352	— .20	37,38	0.4219	0.4200	+ .10
8	74,75	0.2901	0.2916	— .08	44,45	0.2625	0.2612	+ .07
10	73,74	0.3949	0.3975	— .14	45,46	0.1579	0.1584	— .03
11	72,73	0.5386	0.5364	+ .12	46	0.5189	0.5141	+ .25
14	64	0.4098	0.4100	— .01	54,55	0.6420	0.6401	+ .10
16	62,63	0.7976	0.7986	— .05	55,56	0.7551	0.7531	+ .10
17	61,62	0.3892	0.3901	— .05	57,58	0.1654	0.1615	+ .21
18	59,60	0.8448	0.8468	— .12	58,59	0.7078	0.7072	+ .03
20	59,60	0.5010	0.4991	+ .10	59,60	0.0539	0.0565	— .14
22	57,58	0.5558	0.5589	— .16	61	0.4941	0.4908	+ .19
23	56,57	0.1874	0.1871	+ .02	62,63	0.3664	0.3642	+ .12
24	54,55	0.0610	0.0612	— .01	64,65	0.4884	0.4902	— .10
25	53,54	0.4784	0.4780	+ .02	65,66	0.0745	0.0722	+ .12
26	53,54	0.3661	0.3669	— .04	65,66	0.1869	0.1885	— .09
27	53,54	0.1111	0.1118	— .04	65,66	0.4440	0.4401	+ .21
28	52,53	0.8736	0.8748	— .06	65,66	0.6789	0.6774	+ .08
29	52,53	0.2845	0.2878	— .17	66,67	0.2669	0.2612	+ .30
45	25	0.4730	0.4744	— .07	93,94	0.5818	0.5840	— .12
		Schl.	Hays	*S—H*		Schl.	Hays	*S—H*
				″				″
15	63,64	0.7105	0.7124	—0.10	54,55	0.8412	0.8419	—0.03
15	63,64	0.7130	0.7108	+ .12	54,55	0.8408	0.8409	— .01
1	98,99	0.2198	0.2182	+ .08	20,21	0.3396	0.3376	+ .10
2	97,98	0.2161	0.2202	— .22	21,22	0.3398	0.3376	+ .12
5	85,86	0.3189	0.3158	+ .16	33,34	0.2370	0.2384	— .07
7	78,79	0.4000	0.3978	+ .12	40,41	0.1598	0.1588	+ .05
7A	74,75	0.3018	0.3010	+ .04	44,45	0.2538	0.2531	+ .04
19	59,60	0.8144	0.8172	— .15	58,59	0.7409	0.7334	+ .39
23A	55,56	0.1681	0.1626	+ .29	63,64	0.3889	0.3884	+ .03
31	51,52	0.6894	0.6871	+ .12	66,67	0.8675	0.8676	— .01
32	49,50	0.8098	0.8086	+ .06	68,69	0.7445	0.7426	+ .10
33	48,49	0.1569	0.1561	+ .04	70,71	0.3988	0.4004	— .08
34	47,48	0.5111	0.5140	— .15	71	0.5398	0.5425	— .15
35	45,46	0.5094	0.5122	— .15	73	0.5412	0.5445	— .18
36	44	0.5342	0.5275	+ .36	74,75	0.5245	0.5174	+ .38
37	43,44	0.8969	0.8980	— .05	74,75	0.6581	0.6594	— .07
38	40,41	0.2764	0.2762	+ .01	78,79	0.2790	0.2751	+ .21
39	39,40	0.5344	0.5344	.00	79	0.5228	0.5226	+ .01
40	37,38	0.6996	0.6971	+ .13	80,81	0.8536	0.8578	— .21
43	29,30	0.8098	0.8078	+ .11	88,89	0.7468	0.7445	+ .13
44	29,30	0.2696	0.2618	+ .41	89,90	0.2901	0.2881	+ .11
45	25	0.4734	0.4758	— .12	93,94	0.5821	0.5852	— .16

TABLE III.—(*Continued.*) PLATE II: y MEASUREMENTS.

Star.	y direct.				y reversed.			
	Line	$\frac{1}{2}m$, or Scale *minus* Star.		$K-H$	Line.	$\frac{1}{2}m$, or Scale *minus* Star.		$K-H$
		Kretz.	Hays.			Kretz.	Hays.	
15	51	0.4148	0.4171	−0″.12	68	0.1352	0.1344	+0″.04
15					68	0.1355	0.1368	− .07
2	48	0.0102	0.0088	+ .07	71	0.5406	0.5432	− .14
4	16	0.3411	0.3412	− .01	103	0.2192	0.2192	.00
6	65	0.6206	0.6175	+ .16	53	0.9330	0.9344	− .08
8	66	0.3665	0.3671	− .03	53	0.1856	0.1838	+ .10
10	44	0.3996	0.3972	+ .13	75	0.1539	0.1514	+ .13
11	38	0.6644	0.6645	− .01	80	0.8918	0.8906	+ .07
14	72	0.3570	0.3578	− .04	47	0.1970	0.1950	+ .11
16	17	0.1786	0.1791	− .03	102	0.3780	0.3768	+ .06
17	35	0.2662	0.2641	+ .11	84	0.2851	0.2858	− .04
18	36	0.1135	0.1128	+ .04	83	0.4404	0.4381	+ .12
20	35	0.3360	0.3325	+ .19	84	0.2159	0.2160	− .01
22	67	0.0880	0.0889	− .05	52	0.4618	0.4609	+ .05
23	64	0.6105	0.6099	+ .03	54	0.9411	0.9408	+ .03
24	34	0.7494	0.7484	+ .06	84	0.8025	0.8048	− .13
25	45	0 2892	0.2860	+ .17	74	0.2620	0.2612	+ .04
26	22	0.3085	0.3072	+ .07	97	0.2479	0.2501	− .11
28	55	0.3882	0.3879	+ .02	64	0.1601	0.1598	+ .02
29	79	0.0066	0.0085	− .10	40	0.5452	0.5449	+ .02
33	14	0.1540	0.1538	+ .01	105	0.4014	0.3988	+ .14
15	51	0.4176	0.4178	−0″.01	68	0.1374	0.1369	+0″.03
15	51	0.4146	0.4166	− .11	68	0.1348	0.1381	− .17
1	67	0.1062	0.1050	+ .06	52	0.4448	0.4442	+ .03
5	80	0.3721	0.3734	− .07	39	0.1791	0.1778	+ .07
7	32	0.3801	0.3786	+ .08	87	0.1742	0.1741	+ .01
7A	47	0 6575	0.6584	− .04	71	0.8970	0.8958	+ .07
19	77	0.3065	0.3075	− .05	42	0.2455	0.2440	+ .08
23A	66	0.1972	0.1936	+ .19	53	0.3584	0.3549	+ .19
27	44	0.1530	0.1530	.00	75	0.4005	0.3972	+ .17
31	35	0.6549	0.6524	+ .13	83	0.9032	0.9024	+ .05
32	11	0.8212	0.8249	− .21	107	0.7351	0.7302	+ .26
33	14	0.1548	0.1532	+ .08	105	0.4031	0.4030	+ .01
34	47	0.5749	0.5725	+ .13	71	0.9784	0.9769	+ .10
35	84	0.8458	0.8426	+ .16	34	0.7100	0.7115	− .08
36	62	0.2885	0.2879	+ .03	57	0.2629	0.2646	− .09
37	38	0.1672	0.1659	+ .07	81	0.3884	0.3875	+ .05
38	55	0.1725	0.1746	− .11	64	0.3778	0.3762	+ .08
39	61	0.4712	0.4724	− .06	58	0.0776	0.0781	− .03
40	16	0.5089	0.5050	+ .21	103	0.0502	0.0514	− .06
43	58	0.3500	0.3474	+ .14	61	0.2022	0.2029	− .04
44	77	0.7740	0.7744	− .02	41	0.7819	0.7749	+ .37
45	26	0.9096	0.9109	− .06	92	0.6474	0.6468	+ .03

TABLE III.—(*Continued.*) PLATE III: x MEASUREMENTS.

	x direct.				x reversed.			
Star.	Lines.	½ *m*, or Scale *minus* Star.		*S*—*K*	Lines.	½ *m*, or Scale *minus* Star.		*S*—*K*
		Schl.	Kretz.			Schl.	Kretz.	
				″				″
15	56	0.3911	0.3919	—0.04	62,63	0.6618	0.6571	+0.25
2	89,90	0.4000	0.3988	+ .06	29	0.6560	0.6566	— .04
3	88,89	0.2970	0.2958	+ .06	30,31	0.2614	0.2550	+ .34
4	86,87	0.5528	0.5500	+ .16	32	0.5092	0.5078	+ .06
6	73,74	0.3035	0.3024	+ .06	45,46	0.2494	0.2486	+ .04
8	66,67	0.4601	0.4549	+ .28	52	0.5961	0.5900	+ .31
10	65,66	0.5760	0.5751	+ .06	53	0.4779	0.4745	+ .17
11	64,65	0.7194	0.7164	+ .15	53,54	0.8316	0.8298	+ .10
14	56	0.5784	0.5782	+ .01	62,63	0.4718	0.4712	+ .04
16	55	0.4950	0.4929	+ .11	63,64	0.5551	0.5549	+ .02
17	53,54	0.5736	0.5715	+ .10	65	0.4799	0.4765	+ .19
18	52	0.5315	0.5326	— .05	66,67	0.5189	0.5174	+ .07
20	51,52	0.6865	0.6869	— .02	67	0.3662	0.3678	— .08
22	49,50	0.7265	0.7282	— .08	68,69	0.8251	0.8240	+ .05
23	48,49	0.3615	0.3651	— .19	70,71	0.1871	0.1900	— .16
24	46,47	0.2424	0.2431	— .04	72,73	0.3086	0.3092	— .03
26	45,46	0.5581	0.5551	+ .15	73	0.4976	0.4960	+ .10
28	45	0.5479	0.5492	— .07	73,74	0.5059	0.5044	+ .08
29	44,45	0.4485	0.4481	+ .02	74	0.6046	0.6075	— .15
45	17,18	0.1620	0.1652	— .18	101,102	0.3970	0.3919	+ .28
		Kretz.	Hays.	*K*—*H*		Kretz.	Hays.	*K*—*H*
				″				″
15	56	0.3914	0.3921	—0.04	62,63	0.6609	0.6606	+0.01
1	90,91	0.3850	0.3879	— .15	28,29	0.1676	0.1706	— .15
2	89,90	0.4021	0.3982	+ .19	29,30	0.1490	0.1516	— .15
5	77,78	0.4799	0.4805	— .03	41	0.5679	0.5720	— .21
7	70,71	0.5824	0.5838	— .07	48	0.4679	0.4664	+ .08
23A	47,48	0.3338	0.3400	— .33	71,72	0.2149	0.2169	— .12
25	45,46	0.6594	0.6636	— .23	73	0.3872	0.3941	— .37
27	45,46	0.2888	0.2896	— .04	73,74	0.2650	0.2638	+ .07
31	44	0.3776	0.3795	— .10	74,75	0.6784	0.6780	+ .03
32	42	0.5044	0.5028	+ .09	76,77	0.5489	0.5510	— .11
33	40,41	0.3505	0.3565	— .31	78,79	0.2052	0.2025	+ .15
34	39,40	0.6875	0.6896	— .12	79	0.3648	0.3654	— .04
35	37,38	0.6701	0.6732	— .16	81	0.3848	0.3850	— .01
36	36,37	0.2011	0.2008	+ .01	82,83	0.3482	0.3489	— .04
37	36	0.5816	0.5810	+ .03	82,83	0.4754	0.4729	+ .13
39	31,32	0.7004	0.7045	— .22	87	0.3522	0.3499	+ .12
40	30	0.3930	0.3948	— .11	88,89	0.6641	0.6649	— .05
43	22	0.4799	0.4785	+ .07	96,97	0.5762	0.5755	+ .03
44	21,22	0.4258	0.4301	— .24	97	0.6301	0.6301	.00
45	17,18	0.1648	0.1620	+ .14	101,102	0.3924	0.3916	+ .04

TABLE III.—(*Continued.*) PLATE III: y MEASUREMENTS.

	y direct				y reversed.			
Star.	Line.	½ *m*, or Scale *minus* Star.		*S—H*	Line.	½ *m*, or Scale *minus* Star.		*S—H*
		Schl	Hays.			Schl.	Hays	
15	53	0.7856	0.7866	—0″.06	65	0.7708	0.7681	+0″.14
2	50	0.3928	0.3918	+ .05	69	0.1626	0.1632	— .04
3	35	0.8020	0.8015	+ .03	83	0.7534	0.7555	— .11
4	18	0.7200	0.7194	+ .03	100	0.8375	0.8408	— .17
6	67	0.9966	0.9959	+ .05	51	0.5574	0.5572	+ .01
8	68	0.7408	0.7428	— .10	50	0.8144	0.8135	+ .05
10	46	0.7719	0.7692	+ .14	72	0.7849	0.7830	+ .10
11	41	0.0348	0.0328	+ .11	78	0.5232	0.5200	+ .16
14	74	0.7250	0.7204	+ .24	44	0.8316	0.8282	+ .17
16	19	0.5458	0.5422	+ .18	100	0.0146	0.0119	+ .14
17	37	0.6339	0.6324	+ .08	81	0.9212	0.9208	+ .03
18	38	0.4796	0.4758	+ .21	81	0.0778	0.0741	+ .20
20	37	0.7001	0.7011	— .05	81	0.8534	0.8512	+ .12
22	69	0.4481	0.4520	— .20	50	0.1001	0.0995	+ .04
23	66	0.9716	0.9748	— 18	52	0.5775	0.5795	— .11
24	37	0.1121	0.1108	+ .07	82	0.4415	0.4392	+ .13
25	47	0.6516	0.6499	+ .10	71	0.9010	0.8996	+ .08
26	24	0.6665	0.6665	.00	94	0.8871	0.8880	— .04
28	57	0.7496	0.7475	+ .11	61	0.8059	0.8040	+ .10
29	81	0.3720	0.3685	+ .18	38	0.1829	0.1800	+ .15
33	16	0.5105	0.5121	— .10	103	0.0479	0.0425	+ .28
15	53	0.7829	0.7849	—0″.10	65	0.7679	0.7654	+0″.14
1	69	0.4875	0.4878	— .03	50	0.0631	0.0631	.00
5	82	0.7499	0.7450	+ .25	36	0.8035	0.8031	+ .02
7	34	0.7538	0.7535	+ .02	84	0.8054	0.8001	+ .29
23A	68	0.5646	0.5611	+ .19	50	0.9911	0.9874	+ .21
27	46	0.5160	0.5145	+ .08	73	0.0391	0.0369	+ .12
31	38	0.0155	0.0181	— .14	81	0.5379	0.5371	+ .04
32	14	0.1861	0.1812	+ .25	105	0.3760	0.3750	+ .05
33	16	0.5112	0.5112	.00	103	0.0484	0.0438	+ .24
34	49	0.9341	0.9330	+ .05	69	0.6175	0.6154	+ .11
35	87	0.2068	0.2039	+ .15	32	0.3486	0.3469	+ .08
36	64	0.6476	0.6454	+ .12	54	0.9068	0.9066	+ .02
37	40	0.5184	0.5215	— .16	79	0.0340	0.0320	+ .11
39	63	0.8299	0.8256	+ .22	55	0.7232	0.7225	+ .03
40	18	0.8654	0.8618	+ .20	100	0.6912	0.6911	+ .01
43	60	0.7026	0.7032	— .03	58	0.8524	0.8500	+ .13
44	80	0.1296	0.1265	+ .17	39	0.4255	0.4234	+ .12
45	29	0.2606	0.2582	+ .13	90	0.2991	0.2939	+ .28

TABLE III.—(*Continued.*) PLATE IV: *x* MEASUREMENTS.

Star.	*x* direct.				*x* reversed.			
	Lines.	½ *m*, or Scale *minus* Star.		*S*—*K*	Lines.	½ *m*, or Scale *minus* Star.		*S*—*K*
		Schl.	Kretz.			Schl.	Kretz.	
15	58,59	0.1086	0.1090	—0″.02	60,61	0.4401	0 4376	+0″.13
15	58,59	0.1098	0.1102	— .02	60,61	0.4404	0.4382	+ .12
2	91,92	0.6132	0.6136	— .02	27	0.4422	0.4411	+ .06
3	90,91	0.4950	0.4922	+ .15	28	0.5600	0.5594	+ .04
4	88,89	0.7311	0.7309	+ .01	29 30	0.8258	0.8249	+ .05
6	75,76	0.5378	0.5355	+ .12	43	0 5160	0 5156	+ .02
8	68,69	0.7006	0.6994	+ .06	50	0.3525	0.3500	+ .13
10	67,68	0.7929	0.7919	+ .06	50,51	0.7615	0.7609	+ .03
11	67	0.4274	0.4251	+ .12	51,52	0 6255	0.6258	— .02
14	58,59	0.3225	0.3204	+ .11	60,61	0 2276	0.2272	+ .02
16	57,58	0.1772	0.1769	+ .02	61,62	0.3724	0 3735	— .06
17	55,56	0.7785	0.7760	+ .13	62,63	0.7741	0.7760	— .09
18	54 55	0.2394	0.2390	+ .02	64,65	0.3106	0.3105	+ .01
20	54	0.3919	0.3916	+ .02	64,65	0.6571	0.6581	— .05
22	52	0.4664	0.4679	— .08	66,67	0.5841	0.5841	.00
23	50,51	0.5970	0.5962	+ .04	68	0.4560	0.4542	+ .10
24	48,49	0.4505	0.4506	— .01	70	0.6004	0.6036	— .17
25	48	0.3772	0.3728	+ .23	70,71	0.6758	0.6746	+ .06
26	47,48	0.7520	0.7505	+ .07	70.71	0.8045	0.8032	+ .08
27	47,48	0.5058	0.5064	— .03	71	0.5465	0.5438	+ .15
28	47,48	0.2779	0.2762	+ .08	71,72	0.2745	0.2740	+ .03
29	46,47	0.7029	0.7000	+ .15	72	0 3510	0.3495	+ .08
45	19,20	0.3636	0.3658	— .12	99,100	0.1926	0.1918	+ .04
15	58	0.6106	0.6114	—0″.03	60,61	0.4404	0.4411	—0″.03
15	58	0.6108	0.6094	+ .06	60,61	0.4415	0.4379	+ .19
1	92,93	0.6165	0.6235	— .37	26	0.4415	0.4395	+ .10
2	91,92	0.6136	0.6129	+ .04	27	0.4419	0.4405	+ .07
5	79,80	0.7375	0.7375	.00	38,39	0.8199	0.8202	— .01
7	72,73	0.7816	0.7840	— .12	45,46	0.7742	0.7744	— .02
7A	68,69	0.6918	0.6942	— .13	50	0 3619	0 3602	+ .09
19	54,55	0.2284	0.2284	.00	64 65	0.3215	0.3205	+ .05
23A	49,50	0.5751	0 5765	— .07	69	0 4772	0.4790	— .10
31	46	0.5839	0.5828	+ .05	72,73	0.4711	0.4691	+ .11
32	44,45	0.1821	0.1831	— .05	74.75	0.3680	0.3692	— .06
33	42,43	0.5291	0.5280	+ .05	76	0.5155	0.5175	— .11
34	42	0 4086	0.4081	+ .03	76,77	0.6442	0.6416	+ .14
35	40	0.4341	0.4365	— .13	78,79	0.6210	0 6191	+ .10
36	38,39	0.4386	0.4406	— .11	80	0.6144	0.6154	— .06
37	38,39	0.2875	0.2868	+ .04	80,81	0.2640	0.2649	— .05
38	34,35	0.6826	0.6850	— .12	84	0.3724	0.3726	— .02
39	34	0.4401	0.4415	— .07	84,85	0.6141	0.6149	— .04
40	32	0.5829	0.5836	— .03	86,87	0.4729	0.4742	— .07
43	24,25	0.2176	0.2154	+ .12	94,95	0.3385	0.3400	— .08
44	23.24	0.6931	0.6961	— .15	95	0.3649	0.3628	+ .12
45	19,20	0.3628	0.3605	+ .12	99,100	0.1922	0.1905	+ .09

TABLE III.—(*Continued.*) PLATE IV: y MEASUREMENTS.

Star.	y direct.				y reversed.			
	Line.	½ *m*, or Scale *minus* Star.		$S—K$	Line.	½ *m*, or Scale *minus* Star.		$S—K$.
		Schl.	Kretz.			Schl	Kretz.	
15	54	0.3544	0.3561	—0′.09	65	0.1952	0.1934	+0″.10
15	54	0.3545	0.3578	— 17	65	0.1926	0.1939	— .07
2	50	0.9360	0.9344	+ .07	68	0.6195	0.6199	— .02
3	36	0.3470	0.3464	+ .03	83	0.2059	0.2051	+ .04
4	19	0.2672	0 2691	— .10	100	0.2875	0.2898	— .12
6	68	0.5526	0 5525	+ .01	50	0.9996	1.0015	— .12
8	69	0 2996	0 3001	— .03	50	0.2510	0.2481	+ .15
10	47	0.3356	0.3349	+ .03	72	0.2148	0.2164	— .08
11	41	0.5992	0.5962	+ .16	77	0.9564	0.9561	+ .03
14	75	0.2926	0.2945	— .10	44	0.2558	0.2565	— .04
16	20	0.1172	0.1185	— .07	99	0.4378	0.4361	+ .09
17	38	0.2076	0.2078	— .01	81	0.3446	0.3442	+ .02
18	39	0.0536	0.0534	+ .01	80	0.4979	0.4991	— .06
20	38	0.2798	0.2785	+ .07	81	0.2716	0.2736	— .11
22	70	0.0256	0.0255	+ .01	49	0.5252	0.5246	+ .03
23	67	0.5522	0.5525	— .02	52	—.0032	0.0002	— .18
24	37	0.6928	0.6925	+ .02	81	0.8572	0.8588	— .10
25	48	0.2345	0 2330	+ .08	71	0.3155	0.3162	— .04
26	25	0.2515	0.2508	+ .04	94	0.3014	0.3042	— .15
28	58	0.3315	0.3305	+ .05	61	0.2180	0.2182	— .01
29	81	0.9495	0.9505	— .06	37	0.6024	0.6021	+ .02
33	17	0.1019	0.0998	+ .11	102	0.4535	0.4555	— .11
15	54	0.3538	0.3568	—0″.15	65	0.1951	0.1922	+0″.15
15	54	0.3562	0.3579	— .08	65	0.1929	0.1904	+ .13
1	70	0.0282	0.0304	— .12	49	0.5239	0.5224	+ .07
5	83	0.2979	0.2979	.00	36	0.2529	0.2540	— .06
7	35	0.3186	0.3182	+ .02	84	0.2356	0.2362	— .03
7A	50	0.5930	0.5936	— .03	68	0.9646	0.9656	— .07
19	80	0.2471	0.2455	+ .08	39	0.3060	0.3088	— .15
23A	69	0.1386	0.1401	— .08	50	0.4115	0.4120	— .03
27	47	0.0961	0.0966	— .03	72	0.4552	0.4564	— .06
31	38	0 5966	0.5961	+ .02	80	0.9584	0.9589	— .04
32	14	0.7720	0.7728	— .04	104	0.7861	0.7886	— .13
33	17	0.1015	0.1024	— .05	102	0.4555	0.4562	— .04
34	50	0 5242	0.5254	— .06	69	0.0256	0.0276	— .11
35	87	0.7922	0.7922	.00	31	0.7645	0.7664	— .10
36	65	0.2356	0.2331	+ .13	54	0.3152	0.3154	— .01
37	41	0.1111	0.1115	— .02	78	0.4406	0.4410	— .02
38	58	0.1198	0.1186	+ .06	61	0.4311	0.4320	— .05
39	64	0.4198	0.4202	— .02	55	0.1292	0.1296	— .02
40	19	0.4612	0.4622	— .05	100	0.0895	0.0895	.00
43	61	0.2991	0.3002	— .06	58	0.2488	0.2490	— .01
44	80	0.7300	0.7276	+ .13	38	0.8281	0.8304	— .13
45	29	0.8686	0.8679	+ .03	89	0.6874	0.6874	.00

TABLE III.—(*Continued.*) PLATE V: x MEASUREMENTS.

Star.	x direct.				x reversed.			
	Lines	½ m. or Scale *minus* Star. Schl.	½ m. or Scale *minus* Star. Kretz.	S—K	Lines.	½ m. or Scale *minus* Star. Schl.	½ m. or Scale *minus* Star. Kretz.	S—K
15	55,56	0.2626	0.2598	+0″.15	63,64	0.3082	0.3041	+0″.22
15	55,56	0.2629	0.2598	+ .16	63,64	0.3078	0.3055	+ .12
2	88,89	0.7681	0.7676	+ .03	29,30	0.8032	0.8031	+ .01
3	87,88	0.6692	0.6708	— .08	30,31	0.9018	0.9005	+ .06
4	85,86	0.9279	0.9281	— .02	32,33	0.6450	0.6451	— .01
6	72,73	0.6664	0.6684	— .11	45,46	0.8999	0.9011	— .07
8	65,66	0.8274	0.8279	— .03	52,53	0.7400	0.7415	— .08
10	64,66	0.4472	0.4454	+ .10	53,54	0.6195	0.6194	+ .01
11	64,65	0.0944	0.0921	+ .12	54,55	0.4770	0.4764	+ .03
14	55,56	0.4405	0.4400	+ .03	63,64	0.1269	0.1251	+ .10
16	54,55	0.3751	0.3738	+ .07	64,65	0.1938	0.1938	.00
17	52,54	0.4486	0.4476	+ .05	65,66	0.6221	0.6204	+ .09
18	51,52	0.4046	0.4030	+ .08	67,68	0.1645	0.1631	+ .07
20	51,52	0.0611	0.0592	+ .10	67,68	0.5110	0.5089	+ .11
22	49,50	0.0939	0.0929	+ .05	69,70	0.4755	0.4735	+ .11
23	47,48	0.7248	0.7234	+ .07	70,71	0.8448	0.8422	+ .14
24	45,46	0.6199	0.6192	+ .04	72,74	0.4516	0.4486	+ .17
25	45,46	0.0336	0.0326	+ .05	73,74	0.5389	0.5368	+ .11
26	44,46	0.4384	0.4380	+ .02	73,74	0.6342	0.6314	+ .15
27	44,45	0.6610	0.6584	+ .14	73,74	0.9106	0.9106	.00
28	44,45	0.4170	0.4146	+ .13	74,75	0.1540	0.1514	+ .14
29	43,44	0.8122	0.8128	— .03	74,75	0.7590	0.7554	+ .19
45	16,17	0.5412	0.5450	— .20	102,103	0.0298	0.0298	.00
15	55,56	0.2614	0.2596	+0″.10	63,64	0.3075	0.3050	+0″.13
15	55,56	0.2590	0.2598	— .04	63,64	0.3069	0.3049	+ .11
1	89,90	0.7531	0.7504	+ .14	28,29	0.8219	0.8161	+ .31
2	88,89	0.7692	0.7650	+ .22	29,30	0.8012	0.8020	— .05
5	76,77	0.8410	0.8396	+ .08	41,42	0.7296	0.7272	+ .13
7	69,71	0.4560	0.4555	+ .02	48,49	0.6126	0.6108	+ .10
19	51,52	0.3436	0.3415	+ .11	67,68	0.2275	0.2262	+ .07
23A	46,47	0.7032	0.7029	+ .02	71,72	0.8665	0.8656	+ .04
31	43,44	0.2522	0.2494	+ .15	75,76	0.3184	0.3155	+ .15
32	41,42	0.3892	0.3901	— .05	77,78	0.1858	0.1832	+ .14
34	39,40	0.0630	0.0658	— .15	79,80	0.5071	0.5039	+ .17
35	37,38	0.0308	0.0279	+ .15	81,82	0.5371	0.5326	+ .24
37	35,36	0.4526	0.4510	+ .08	83,84	0.1158	0.1126	+ .17
39	31,32	0.0745	0.0725	+ .11	87,88	0.4980	0.4962	+ .10
40	29,30	0.2818	0.2772	+ .24	89,90	0.2950	0.2902	+ .25
43	21,22	0.3564	0.3550	+ .07	97,98	0.2196	0.2159	+ .20
44	20,21	0.7966	0.7962	+ .02	97,98	0.7794	0.7735	+ .31
45	16,17	0.5421	0.5444	— .12	102,103	0.0304	0.0251	+ .28

TABLE III.—(*Continued.*) PLATE V: y MEASUREMENTS.

	y direct.				y reversed.			
Star.	Line.	½ *m*, or Scale *minus* Star.		$S—K$	Line.	½ *m*, or Scale *minus* Star.		$S—K$
		Schl.	Kretz.			Schl.	Kretz.	
15	54	0.7016	0.7006	+0″.05	64	0.8646	0.8650	—0″.02
15	54	0.6999	0.7008	— .05	64	0.8626	0.8652	— .14
2	51	0.3171	0.3152	+ .10	68	0.2526	0.2556	— .16
3	36	0.7258	0.7270	— .06	82	0.8448	0.8426	+ .11
4	19	0.6431	0.6422	+ .05	99	0.9318	0.9300	+ .08
6	68	0.9181	0.9175	+ .02	50	0.6506	0.6496	+ .05
8	69	0.6558	0.6568	— .05	49	0.9089	0.9072	+ .10
10	47	0.6930	0.6931	— .01	71	0.8759	0.8748	+ .06
11	41	0.9518	0.9546	— .13	77	0.6155	0.6144	+ .06
14	75	0.6389	0.6386	+ .02	43	0.9291	0.9300	— .04
16	20	0.4612	0.4616	— .02	99	0.1106	0.1068	+ .20
17	38	0.5500	0.5489	+ .06	81	0.0182	0.0166	+ .08
18	39	0.3969	0.3975	— .03	80	0.1698	0.1715	— .09
20	38	0.6178	0.6168	+ .05	80	0.9494	0.9476	+ .08
22	70	0.3664	0.3648	+ .08	49	0.2002	0.2016	— .07
23	67	0.8894	0.8892	+ .02	51	0.6755	0.6768	— .07
24	38	0.0304	0.0291	+ .07	81	0.5392	0.5402	— .05
25	48	0.5638	0.5661	— .12	71	—.0008	—.0005	— .02
26	25	0.5840	0.5829	+ .06	94	—.0120	—.0119	— .01
27	47	0.4309	0.4311	— .01	72	0.1349	0.1350	— .01
28	58	0.6628	0.6626	+ .01	60	0.9031	0.9042	— .05
29	82	0.2832	0.2811	+ .11	37	0.2871	0.2846	+ .13
15	54	0.7029	0.7028	+0″.01	64	0.8622	0.8644	—0″.13
15	54	0.7035	0.7011	+ .13	64	0.8644	0.8636	+ .03
1	70	0.4172	0.4164	+ .04	49	0.1516	0.1570	— .29
5	83	0.6724	0.6675	+ .26	35	0.8962	0.8986	— .12
7	35	0.6772	0.6771	+ .01	83	0.8942	0.8971	— .14
19	80	0.5896	0.5870	+ .14	39	—.0152	—.0150	— .01
23A	69	0.4802	0.4760	+ .22	50	0.0929	0.0920	+ .05
31	38	0.9318	0.9305	+ .08	80	0.6404	0.6350	+ .29
32	15	0.1042	0.1020	+ .12	104	0.4722	0.4699	+ .12
34	50	0.8502	0.8475	+ .15	68	0.7165	0.7156	+ .05
35	88	0.1154	0.1148	+ .03	31	0.4542	0.4576	— .18
37	41	0.4381	0.4368	+ .07	78	0.1349	0.1339	+ .05
39	64	0.7380	0.7364	+ .08	54	0.8279	0.8278	+ .01
40	19	0.7798	0.7792	+ .03	99	0.7938	0.7948	— .06
43	61	0.6096	0.6090	+ .03	57	0.9594	0.9584	— .04
44	81	0.0361	0.0339	+ .12	38	0.5328	0.5342	— .07
45	30	0.1700	0.1699	+ .01	89	0.3978	0.4001	— .13

TABLE III.—(*Continued.*) PLATE VII: *x* MEASUREMENTS.

Star.	*x* direct.				*x* reversed.			
	Lines.	½ *m*, or Scale *minus* Star.		*S—H*	Lines.	½ *m*, or Scale *minus* Star.		*S—H*
		Schl.	Hays.			Schl.	Hays.	
15	61,62	0.6390	0.6438	—0″.25	56,58	0.4129	0.4134	—0″.03
2	95,96	0.1465	0.1489	— .13	23,24	0.4122	0.4078	+ .23
3	93,95	0.5530	0.5496	+ .17	24,25	0.5062	0.5049	+ .07
4	92,93	0.3122	0.3115	+ .04	26,27	0.2438	0.2468	— .16
6	78,80	0.5484	0.5484	.00	39,40	0.5079	0.5094	— .08
8	72 73	0.2074	0.2076	— .01	46,47	0.3484	0.3449	+ .18
10	71,72	0.3296	0.3339	— .23	47,48	0.2242	0.2252	— .05
11	70,71	0.4775	0.4796	— .11	47,49	0.5779	0.5730	+ .25
14	61,62	0.8200	0.8219	— .10	56,57	0.7348	0.7306	+ .22
16	60,61	0.7609	0.7619	— .05	57.58	0.7938	0.7931	+ .03
17	59,60	0.3314	0.3268	+ .24	59,60	0.2208	0.2222	— .07
18	57,58	0.7879	0.7915	— .20	60,61	0.7640	0.7655	— .07
20	57,58	0.4450	0.4424	+ .14	60,62	0.6079	0.6100	— .10
22	55,56	0.4754	0.4781	— .14	62,64	0.5755	0.5742	+ .07
23	54,55	0.1081	0.1092	— .06	64,65	0.4446	0.4468	— .11
24	51,53	0.5110	0.5112	— .01	66,67	0.5442	0.5444	— .01
25	51,52	0.4162	0.4139	+ .12	67,68	0 1366	0.1356	+ .05
26	51,52	0.3231	0.3251	— .10	67,68	0.2321	0.2316	+ .03
27	50,52	0.5444	0.5456	— .06	67,68	0.5095	0.5095	.00
28	50,51	0.8028	0.8031	— .01	67,68	0.7540	0.7515	+ .13
29	50.51	0.1946	0.1925	+ .11	68,69	0 3584	0.3595	— .06
31	49,50	0.6379	0.6386	— .04	68.70	0.4170	0.4178	— .04
32	47,48	0.7781	0.7770	+ .06	70,71	0.7778	0.7756	+ .11
33	46,47	0.1226	0.1226	.00	72,73	0.4316	0.4350	— .18
45	22,24	0.4344	0.4370	— .13	95,96	0.6214	0.6179	+ .19
		Schl.	Kretz	*S—K*		Schl.	Kretz.	*S—K*
15	61,62	0.6420	0.6444	—0″.12	56,58	0.4105	0.4090	+0″.08
1	96,97	0.1244	0.1286	— .22	22,23	0.4282	0.4268	+ .07
2	95,96	0.1474	0.1480	— .03	23,24	0.4101	0.4068	+ .17
5	83,84	0.2168	0.2158	+ .05	35,36	0.3389	0.3389	.00
7	76,77	0.3461	0.3411	+ .26	42,43	0.2086	0.2081	+ .03
7A	72,73	0.2332	0.2351	— .10	46,47	0.3231	0.3216	+ .08
19	57.58	0.7251	0.7224	+ .14	60,61	9.8312	0.8338	— .14
21	56,58	0.4262	0.4250	+ .06	61.62	0.6336	0.6280	+ .30
23A	52,54	0 5909	0.5854	+ .28	65,66	0.4660	0.4674	— .07
34	45,46	0.4486	0.4469	+ .09	73.74	0.1078	0.1046	+ .17
35	43,44	0.4162	0.4164	— .01	75,76	0.1359	0.1390	— .16
36	41,43	0.4652	0.4626	+ .14	76,77	0.5950	0.5931	+ .10
37	41,42	0.8426	0.8446	— .12	76,77	0.7156	0.7064	+ .49
38	38,39	0.2091	0.2134	— .23	80,81	0.3486	0.3459	+ .14
39	37,38	0.4620	0.4608	+ .06	80,82	0.5946	0.5924	+ .12
40	35,36	0.6735	0.6731	+ .02	82,84	0.3860	0.3824	+ .19
41	31,32	0.6124	0.6054	+ .37	86,88	0.4504	0.4526	— .12
42	29,30	0.6276	0.6230	+ .24	88,90	0.4315	0.4300	+ .07
43	27,28	0.7438	0.7431	+ .04	90,91	0.8136	0.8128	+ .03
44	27,28	0.1826	0.1789	+ .20	91,92	0.3741	0.3744	— .02
45	22,24	0.4362	0.4340	+ .11	95,96	0.6239	0.6222	+ .09

TABLE III.—(*Continued.*) PLATE VII: *y* MEASUREMENTS.

Star.	*y* direct.				*y* reversed.			
	Line.	½ *m*, or Scale *minus* Star.		*S—K*	Line.	½ *m*, or Scale *minus* Star.		*S—K*
		Schl.	Kretz.			Schl.	Kretz.	
15	62	0.0196	0.0186	+0″.05	57	0.5301	0.5302	—0″.01
2	58	0.6448	0.6446	+ .01	60	0.9095	0.9045	+ .28
3	44	0.0536	0.0534	+ .01	75	0.4972	0.4942	+ .16
4	26	0.9754	0.9744	+ .07	92	0.5794	0.5774	+ .11
6	76	0.2415	0.2414	+ .01	43	0.3114	0.3072	+ .22
8	76	0.9804	0.9799	+ .02	42	0.5731	0.5720	+ .06
10	55	0.0164	0.0149	+ .08	64	0.5348	0.5346	+ .01
11	49	0.2788	0.2782	+ .03	70	0.2735	0.2714	+ .11
14	82	0.9624	0.9610	+ .06	36	0.5922	0.5928	— .03
16	27	0.7882	0.7840	+ .23	91	0.7689	0.7664	+ .13
17	45	0.8736	0.8712	+ .14	73	0.6788	0.6784	+ .02
18	46	0.7182	0.7169	+ .07	72	0.8365	0.8336	+ .16
20	45	0.9394	0.9379	+ .10	73	0.6142	0.6149	— .04
22	77	0.6870	0.6864	+ .03	41	0.8685	0.8691	— .04
23	75	0.2095	0.2090	+ .03	44	0.3416	0.3448	— .16
24	45	0.3472	0.3462	+ .05	74	0.2028	0.2011	+ .09
25	55	0.8854	0.8852	+ .02	63	0.6631	0.6628	+ .02
26	32	0.9052	0.9058	— .02	86	0.6512	0.6496	+ .08
27	54	0.7488	0.7494	— .03	64	0.8004	0.7996	+ .05
28	65	0.9808	0.9806	+ .01	53	0.5726	0.5720	+ .03
29	89	0.6049	0.6022	+ .14	29	0.9515	0.9535	— .12
31	46	0.2505	0.2515	— .05	73	0.3002	0.3026	— .13
32	22	0.4230	0.4215	+ .08	97	0.1355	0.1334	+ .11
33	24	0.7514	0.7492	+ .11	94	0.8048	0.8038	+ .05
		Kretz.	Hays	*K—H*		Kretz.	Hays.	*K—H*
15	62	0.0182	0.0246	—0″.34	57	0.5318	0.5329	—0″.06
1	77	0.7418	0.7462	— .23	41	0.8111	0.8120	— .04
5	90	0.9979	0.9966	+ .08	28	0.5592	0.5605	— .06
7	43	—.0005	—.0001	— .02	76	0.5508	0.5521	— .06
7A	58	0.2669	0.2690	— .11	61	0.2860	0.2868	— .04
19	87	0.9085	0.9064	+ .10	31	0.6464	0.6486	— .12
21	86	0.3856	0.3829	+ .14	33	0.1770	0.1775	— .02
23A	76	0.7939	0.7956	— .08	42	0.7582	0.7600	— .10
33	24	0.7534	0.7530	+ .02	94	0.8038	0.8059	— .12
34	58	0.1652	0.1675	— .12	61	0.3841	0.3861	— .11
35	95	0.4320	0.4320	.00	24	0.1251	0.1244	+ .04
36	72	0.8776	0.8750	+ .14	46	0.6749	0.6749	.00
37	48	0.7515	0.7538	— .12	70	0.8013	0.8045	— .17
38	65	0.7550	0.7541	+ .05	53	0.8013	0.8026	— .07
39	72	0.0530	0.0519	+ .06	47	0.5000	0.5019	— .10
40	27	0.0934	0.0952	— .10	92	0.4606	0.4615	— .05
41	54	0.4615	0.4634	— .10	65	0.0902	0.0882	+ .11
42	54	0.3646	0.3646	.00	65	0.1885	0.1909	— .13
43	68	0.9215	0.9211	+ .01	50	0.6322	0.6345	— .12
44	88	0.3458	0.3438	+ .10	31	0.2065	0.2076	— .06
45	37	0.4842	0.4869	— .14	82	0.0679	0.0672	+ .04

TABLE III.—(*Continued.*) PLATE VIII: *x* MEASUREMENTS.

Star.	*x* direct.				*x* reversed.			
	Lines.	½ *m*, or Scale *minus* Star.		*S—K*	Lines	½ *m*, or Scale *minus* Star.		*S—K*
		Schl.	Kretz.			Schl	Kretz.	
15	60,61	0.2671	0.2648	+0″.12	58,59	0.2850	0 2819	+0″.16
15					58,59	0.2851	0.2828	+ .12
2	93.94	0.7701	0.7728	— .14	24,25	0.7856	0.7825	+ .17
3	92,93	0.6742	0.6731	+ .06	25,27	0.3849	0.3842	+ .04
4	90,92	0.4280	0.4276	+ .02	27,28	0.6299	0.6285	+ .07
6	77.78	0.6768	0.6800	— .17	40,42	0 3745	0 3741	+ .02
8	70,72	0.3415	0.3375	+ .21	47.48	0.7154	0.7150	+ .02
10	69 71	0.4545	0.4509	+ .19	48,49	0.6002	0.5968	+ .18
11	68,70	0.6009	0.6011	— .01	49 50	0 4522	0.4505	+ .09
14	60 61	0.4509	0.4502	+ .04	57.59	0.5990	0.5988	+ .02
16	59,60	0.3821	0.3795	+ .14	59,60	0.1725	0 1725	.00
17	57.59	0.4562	0.4515	+ .25	60,61	0.5979	0.5978	+ .01
18	56.57	0.4119	0.4091	+ .15	62,63	0.1374	0.1385	— .06
20	55.57	0.5689	0.5650	+ .21	62.63	0.4841	0.4874	— .18
22	53 55	0.6064	0 6061	+ .01	64,65	0.4450	0.4465	— .08
23	52 53	0.7400	0.7380	+ .11	65.66	0.8161	0 8162	.00
24	50.51	0.6309	0.6234	+ .40	67,69	0.4269	0.4252	+ .09
25	49 51	0.5430	0.5401	+ .15	68,69	0 5071	0 5089	— .10
26	49 51	0.4416	0.4394	+ .12	68,69	0 6129	0 6110	+ .10
27	49 50	0.6729	0.6702	+ .14	68,70	0 3799	0.3794	+ .03
28	49 50	0.4262	0 4281	— .10	68,70	0.6234	0 6234	.00
29	48.49	0 8270	0.8258	+ .07	69,70	0.7252	0.7242	+ .05
31	48,49	0.2589	0.2556	+ .17	70,71	0.2974	0 2940	+ .18
45	21,22	0.5558	0.5545	+ .07	96 98	0.5000	0.4980	+ .10
		Schl.	Hays	*S—H*		Schl.	Hays.	*S—H*
15	60,61	0.2681	0.2700	—0″.10	58 59	0.2839	0.2840	—0″.01
15	60 61	0.2664	0.2661	+ .02	58,59	0.2852	0.2856	— .02
1	94.95	0.7576	0.7529	+ .24	23,24	0.8044	0.7984	+ .32
2	93,94	0.7709	0.7736	— .14	24.25	0 7872	0.7855	+ .08
5	81,82	0.8511	0.8485	+ .13	36,37	0.7059	0 7065	— .03
7	74,76	0.4639	0.4646	— .03	43.44	0.5938	0.5896	+ .22
7A	70.72	0.3661	0.3594	+ .35	47,48	0.6921	0.6902	+ .10
19	56.57	0.3584	0.3575	+ .05	62 63	0.1961	0.1901	+ .31
23A	51,52	0.7201	0.7181	+ .10	66,67	0.8364	0.8356	+ .05
32	46,47	0.3970	0.3920	+ .26	72,73	0.1592	0.1631	— .21
33	44.45	0.7401	0.7400	+ .01	73.74	0.8152	0.8174	— .11
34	43,45	0.5712	0 5742	— .17	74,75	0 4800	0.4814	— .07
35	41,43	0.5529	0.5520	+ .04	76 77	9.5016	0.5000	+ .08
36	40,41	0.5946	0.5938	+ .04	77,79	0.4630	0.4615	+ .08
37	40:41	0.4676	0.4679	— .02	77,79	0.5885	0.5921	— .19
38	36,37	0.8402	0.8384	+ .08	81,82	0.7172	0.7172	.00
39	35.37	0.5885	0.5916	— .17	82,83	0.4624	0.4592	+ .17
40	34,35	0.2886	0.2882	+ .02	84,85	0.2649	0.2655	— .03
41	30,31	0.2381	0.2302	+ .42	88,89	0.3200	0.3199	+ .01
42	28,29	0.2592	0.2594	— .01	90,91	0.3016	0.2991	+ .13
43	26,27	0.3708	0.3731	— .12	82,93	0.1818	0.1814	+ .02
44	25,26	0.8192	0.8188	+ .03	92,93	0.7378	0.7345	+ .17
45	21,22	0.5601	0.5591	+ .05	96,98	0.5009	0.4981	+ .14

TABLE III.—(*Continued.*) PLATE VIII: y MEASUREMENTS.

Star.	y direct.				y reversed.			
	Line.	½ *m*, or Scale *minus* Star.		*K—H*	Line.	½ *m*, or Scale *minus* Star.		*K—H*
		Kretz.	Hays.			Kretz.	Hays.	
15	55	0.0068	0.0070	—0″.01	64	0.5411	0.5416	—0″.03
15					64	0.5421	0.5425	— .02
2	51	0.6239	0.6241	— .01	67	0.9258	0.9290	— .19
3	37	0.0348	0.0326	+ .12	82	0.5169	0.5194	— .13
4	19	0.9572	0.9590	— .08	99	0.5984	0.6002	— .10
6	69	0.2228	0.2200	+ .15	50	0.3288	0.3249	+ .21
8	69	0.9606	0.9614	— .03	49	0.5875	0.5898	— .12
10	48	—.0029	0.0000	— .15	71	0.5505	0.5512	— .04
11	42	0.2579	0.2596	— .09	77	0.2900	0.2915	— .08
14	75	0.9466	0.9432	+ .16	43	0.6034	0.6072	— .20
16	20	0.7739	0.7724	+ .07	98	0.7801	0.7820	— .11
17	38	0.8599	0.8614	— .07	80	0.6928	0.6949	— .11
18	39	0.7045	0.7068	— .12	79	0.8506	0.8478	+ .15
20	38	0.9272	0.9284	— .05	80	0.6249	0.6264	— .08
22	70	0.6700	0.6721	— .11	48	0.8775	0.8769	+ .04
23	68	0.1906	0.1938	— .17	51	0.3525	0.3596	— .37
24	38	0.3356	0.3372	— .08	81	0.2140	0.2150	— .05
25	48	0.8722	0.8729	— .03	70	0.6748	0.6775	— .14
26	25	0.8939	0.8966	— .13	93	0.6598	0.6611	— .07
27	47	0.7358	0.7394	— .19	71	0.8111	0.8096	+ .08
28	58	0.9688	0.9678	+ .04	60	0.5792	0.5779	+ .07
29	82	0.5856	0.5869	— .07	36	0.9645	0.9650	— .04
31	39	0.2340	0.2400	— .32	80	0.3161	0.3192	— .16
33	17	0.7346	0.7341	+ .03	101	0.8170	0.8195	— .14
		Schl.	Kretz.	*S—K*		Schl.	Kretz	*S—K*
15	55	0.0095	0.0072	+0″.12	64	0.5411	0.5409	+0″.01
15	55	0.0105	0.0076	+ .15	64	0.5458	0.5418	+ .21
1	70	0.7176	0.7158	+ .09	48	0.8352	0.8331	+ .10
5	83	0.9740	0.9754	— .09	35	0.5774	0.5751	+ .12
7	36	—.0154	—.0178	+ .13	83	0.5680	0.5670	+ .05
7A	51	0.2508	0.2484	+ .13	68	0.3062	0.3025	+ .20
19	80	0.8938	0.8884	+ .28	38	0.6646	0.6609	+ .20
23A	69	0.7815	0.7792	+ .12	49	0.7719	0.7688	+ .16
32	15	0.4090	0.4109	— .10	104	0.1476	0.1456	+ .11
33	17	0.7384	0.7378	+ .03	101	0.8194	0.8171	+ .13
34	51	0.1562	0.1560	+ .01	68	0.3972	0.3955	+ .09
35	88	0.4174	0.4150	+ .13	31	0.1369	0.1330	+ .21
36	65	0.8636	0.8619	+ .10	53	0.6901	0.6880	+ .11
37	41	0.7460	0.7445	+ .08	77	0.8105	0.8101	+ .02
38	58	0.7471	0.7446	+ .13	60	0.8075	0.8049	+ .14
39	65	0.0412	0.0418	— .03	54	0.5091	0.5089	+ .01
40	20	0.0869	0.0869	.00	99	0.4692	0.4708	— .08
41	47	0.4586	0.4596	— .05	72	0.0951	0.0960	— .05
42	47	0.3562	0.3532	+ .16	72	0.2010	0.1981	+ .15
43	61	0.9196	0.9135	+ .33	57	0.6349	0.6349	.00
44	81	0.3348	0.3334	+ .07	38	0.2199	0.2176	+ .12
45	30	0.4771	0.4782	— .06	89	0.0745	0.0785	— .21

TABLE III.—(*Continued.*) PLATE IX: *x* MEASUREMENTS.

Star.	*x* direct.				*x* reversed.			
	Lines.	½ *m*, or Scale *minus* Star.		*S*—*K*	Lines.	½ *m*, or Scale *minus* Star		*S*—*K*
		Schl.	Kretz.			Schl.	Kretz.	
15	54,55	0.8900	0.8901	—0″.01	63,64	0.6599	0.6628	—0″.15
2	88,89	0.3924	0.3978	— .29	30,31	0.1621	0.1625	— .02
3	87,88	0.3025	0.3008	+ .09	31,32	0.2570	0.2544	+ .14
4	85,86	0.5701	0.5648	+ .28	32,34	0.4876	0.4918	— .22
6	72.73	0.2920	0.2899	+ .11	46,47	0.2621	0.2621	.00
8	65,66	0.4511	0 4461	+ .26	53,54	0.1020	0.1029	— .05
10	64,65	0.5751	0.5730	+ .11	53,55	0.4780	0.4776	+ .02
11	63,64	0.7320	0.7318	+ .01	54,55	0.8220	0.8205	+ .07
14	55,56	0.0608	0.0609	— .01	63,64	0.4905	0.4886	+ .10
16	53 55	0.5259	0.5236	+ .12	64,65	0.5291	0.5299	— .04
17	52.53	0.5848	0.5914	— .35	65,67	0.4656	0.4661	— .03
18	50,52	0.5451	0.5448	+ .01	67,68	0.5085	0.5105	— .11
20	50,51	0.6969	0.6962	+ .04	67,68	0.8598	0.8592	+ .04
22	48,49	0.7159	0.7158	+ .01	69,70	0.8362	0.8382	— .10
23	47,48	0.3495	0.3515	— .11	71,72	0.2038	0.2044	— .03
24	45,46	0 2512	0.2520	— .04	73,74	0.2981	0.2989	— .04
25	44.45	0.6609	0.6601	+ .04	73 74	0.8926	0.8914	+ .07
26	44,45	0.5798	0.5791	+ .04	73.75	0.4729	0.4739	— .05
27	44,45	0.2938	0.2900	+ .20	74.75	0.2616	0.2608	+ .04
28	43,45	0.5416	0.5436	— .11	74.75	0.5095	0.5086	+ .05
29	43,44	0 4295	0.4300	— .03	75,76	0.1226	0.1228	— .01
45	16,17	0.1870	0.1888	— .10	102,103	0.3682	0.3689	— .04
		Kretz.	Hays.	*K*—*H*		Kretz.	Hays.	*K*—*H*
15	54,55	0.8899	0.8898	+0″.01	63,64	0.6629	0.6628	+0″01
1	89.90	0.3738	0.3658	+ .42	29,30	0.1809	0.1800	+ .05
2	88,89	0.3938	0.3946	— .04	30,31	0.1600	0.1602	— .01
5	76,77	0.4536	0.4546	— .05	42,43	0.0996	0.0986	+ .05
7	69,70	0.5980	0.5940	+ .21	48,50	0.4599	0.4625	— .13
23A	46,47	0 3264	0.3236	+ .14	72,73	0.2242	0.2258	— .08
31	42,43	0.8836	0.8880	— .22	75,76	0.6685	0.6692	— .04
32	40,42	0 5325	0.5338	— .07	77,78	0.5216	0.5194	+ .12
33	39.40	0.3811	0.3829	— .10	79.80	0.1719	0.1732	— .07
34	38,39	0.6959	0.6980	— .12	79.80	0.8624	0.8601	+ .13
35	36,37	0.6520	0.6511	+ .05	81,82	0.9028	0.9005	+ .13
36	35,36	0.2006	0.1999	+ .04	83,84	0.3488	0.3510	— .12
37	35,36	0.0874	0.0931	— .30	83,84	0.4661	0.4621	+ .21
38	31,32	0.4465	0.4495	— .16	87,88	0.1064	0.1052	+ .06
39	30,31	0.7034	0 6981	+ .28	87,88	0.8530	0.8550	— .10
40	28,29	0.9286	0 9256	+ .17	89,90	0.6300	0.6298	+ .01
43	20,22	0.4879	0.4882	— .01	97,98	0.5671	0.5681	— .05
44	20,21	0.4152	0.4138	+ .07	98,99	0.1415	0.1409	+ .03
45	16,17	0.1885	0.1902	— .09	102,103	0.3685	0.3682	+ .02

TABLE III.—(*Concluded.*) PLATE IX: *y* MEASUREMENTS.

Line.	*y* direct.				*y* reversed.			
	Star.	½ *m*, or Scale *minus* Star.		*K–H*	Line.	½ *m*, or Scale *minus* Star.		*K–H*
		Kretz.	Hays.			Kretz.	Hays.	
15	56	0.6574	0.6586	—0″.06	62	0.8968	0.8969	0″.00
2	53	0.2924	0.2885	+ .21	66	0.2601	0.2619	— .10
3	38	0.7025	0.7022	+ .02	80	0.8546	0.8548	— .02
4	21	0.6201	0.6211	— .05	97	0.9386	0.9390	— .03
6	70	0.8824	0.8836	— .05	48	0.6685	0.6701	— .08
8	71	0.6176	0.6160	+ .08	47	0.9336	0.9311	+ .12
10	49	0.6535	0.6530	+ .02	69	0.8961	0.8986	— .12
11	43	0.9194	0.9174	+ .10	75	0.6335	0.6356	— .11
14	77	0.5956	0.5951	+ .03	41	0.9594	0.9579	+ .10
16	22	0.4234	0.4211	+ .12	97	0.1318	0.1336	— .10
17	40	0.5092	0.5088	+ .02	79	0.0488	0.0450	+ .20
18	41	0.3556	0.3512	+ .23	78	0.2010	0.2028	— .10
20	40	0.5775	0.5768	+ .04	78	0.9788	0.9775	+ .05
22	72	0.3186	0.3181	+ .03	47	0.2341	0.2351	— .05
23	69	0.8454	0.8441	+ .06	49	0.7089	0.7101	— .06
24	39	0.9861	0.9831	+ .17	79	0.5705	0.5735	— .16
25	50	0.5185	0.5192	— .04	69	0.0304	0.0294	+ .05
26	27	0.5389	0.5426	— .20	92	0.0139	0.0171	— .17
27	49	0.3845	0.3856	— .06	70	0.1659	0.1660	— .01
28	60	0.6129	0.6126	+ .02	58	0.9371	0.9361	+ .06
29	84	0.2345	0.2326	+ .10	35	0.3168	0.3154	+ .07
33	19	0.3819	0 3838	— .10	100	0.1718	0.1716	+ .01
		Schl.	Hays.	*S–H*		Schl.	Hays.	*S–H*
15	56	0.6586	0.6598	—0″.06	62	0.8946	0.8964	—0″.11
1	72	0.3909	0.3881	+ .15	47	0.1674	0.1626	+ .25
5	85	0.6366	0.6354	+ .06	33	0.9176	0.9172	+ .03
7	37	0.6385	0.6375	+ .05	81	0.9169	0.9132	+ .21
23A	71	0.4271	0 4246	+ .13	48	0.1265	0.1219	+ .24
31	40	0.8852	0.8874	— .13	78	0.6710	0.6731	— .11
32	17	0.0584	0.0532	+ .28	102	0.5040	0.5041	— .01
33	19	0.3802	0.3842	— .21	100	0.1728	0.1711	+ .09
34	52	0.7965	0.7979	— .07	66	0.7548	0.7551	— .01
35	90	0.0624	0.0638	— .07	29	0.4945	0 4920	+ .13
36	67	0.5094	0.5024	+ .37	52	0.0486	0.0412	+ .39
37	43	0.3850	0.3868	— .10	76	0.1650	0.1701	— .27
38	60	0.3900	0.3834	+ .35	59	0.1671	0.1660	+ .06
39	66	0.6850	0.6826	+ .13	52	0.8684	0.8680	+ .03
40	21	0.7210	0.7229	— .10	97	0.8329	0.8329	.00
43	63	0.5462	0.5432	+ .15	56	0.0040	0.0062	— .12
44	82	0.9712	0.9688	+ .11	36	0.5834	0.5864	— .16
45	32	0.1102	0.1076	+ .14	87	0.4465	0.4474	— .05

III.

Instrumental Corrections.

The first step towards turning the foregoing measures into right ascensions and declinations will be to apply the following instrumental corrections, which are here considered in the order of their application.

1° *Division Errors of the Scale.*

Just before beginning the measurement of the Præsepe plates a thorough examination of the division errors of the scale was completed. The details of this investigation together with the determinations of other constants of the measuring machine are reserved for another publication from this observatory. It will suffice for present purposes to set down merely the final results.

Previous to the above investigation the scale had also been examined by the *Kaiserliche Normal Aichungs Kommission* at Berlin; the results of this determination were published in the "Annals of the New York Academy of Sciences," Vol. IX, page 206. The two determinations agree quite well, the largest difference for any line being 0.″11, and usually the agreement is much closer. As the investigation at Columbia was made with the same microscope and under the same conditions in which the plates were measured, it was thought best to use only our own results, as given in Table IV. The coördinates of a star depend upon several divisions for one plate, and the same star usually comes opposite different divisons for different plates. It follows therefore that our final positions will be nearly independent of inaccuracies in the determination of the division errors; for example, the right ascension of Star 1 depends upon eighteen different lines of the scale and its declination depends upon thirteen. In Table IV the corrections are given in millimetres, and are always to be added to observed readings.

2° *Corrections for Runs and Screw Errors.*

The screw used in the measurements is of such a pitch that two complete turns of the micrometer head correspond to one space on the scale; the micrometer head is divided into one hundred equal parts and may therefore be read directly to half-microns

TABLE IV.—DIVISION ERRORS OF THE SCALE.

Line.	Correction in mm.	Line.	Correction in mm.	Line.	Correction in mm.
0	0.0000	44	+0.0029	88	+0.0025
1	+0.0011	45	+0.0020	89	+0.0026
2	—0.0007	46	+0.0021	90	+0.0018
3	—0.0001	47	+0.0006	91	+0.0027
4	+0.0002	48	+0.0013	92	+0.0025
5	—0.0004	49	+0.0015	93	+0.0026
6	+0.0001	50	+0.0007	94	+0.0026
7	—0.0013	51	+0.0018	95	+0.0026
8	—0.0008	52	+0.0030	96	+0.0019
9	—0.0009	53	+0.0024	97	+0.0008
10	—0.0001	54	+0.0032	98	+0.0014
11	+0.0014	55	+0.0028	99	+0.0004
12	+0.0006	56	+0.0030	100	+0.0019
13	+0.0014	57	+0.0034	101	+0.0004
14	+0.0016	58	+0.0038	102	—0.0005
15	+0.0015	59	+0.0034	103	+0.0002
16	+0.0009	60	+0.0034	104	+0.0014
17	+0.0008	61	+0.0038	105	+0.0009
18	+0.0012	62	+0.0044	106	—0.0012
19	+0.0012	63	+0.0058	107	+0.0002
20	+0.0007	64	+0.0050	108	+0.0012
21	+0.0015	65	+0.0053	109	0.0000
22	+0.0016	66	+0.0059	110	—0.0002
23	+0.0014	67	+0.0050	111	+0.0002
24	+0.0012	68	+0.0052	112	—0.0006
25	+0.0007	69	+0.0057	113	—0.0013
26	+0.0026	70	+0.0054	114	+0.0005
27	+0.0033	71	+0.0056	115	—0.0003
28	+0.0026	72	+0.0047	116	0.0000
29	+0.0020	73	+0.0046	117	+0.0020
30	+0.0035	74	+0.0047	118	+0.0022
31	+0.0030	75	+0.0037	119	+0.0026
32	+0.0022	76	+0.0052	120	+0.0021
33	+0.0024	77	+0.0045	121	+0.0014
34	+0.0013	78	+0.0041	122	+0.0024
35	+0.0032	79	+0.0040	123	+0.0015
36	+0.0024	80	+0.0033	124	+0.0024
37	+0.0025	81	+0.0043	125	+0.0012
38	+0.0016	82	+0.0029	126	+0.0018
39	+0.0025	83	+0.0050	127	+0.0014
40	+0.0033	84	+0.0034	128	+0.0005
41	+0.0020	85	+0.0021	129	+0.0015
42	+0.0025	86	+0.0014	130	0.0000
43	+0.0024	87	+0.0026		

and by estimation to twentieths of a micron. The details of the operation of observing runs were to set the micrometer head at about $5.^{r}0$ and to read on the scale as follows:

Line 70, Line 65, Line 65, Line 70.

These two lines were selected because they have practically the same division errors, thus avoiding an extra correction, and also because they happen to have more accurately determined division errors than most other lines. The correction for runs need not be applied to the separate readings on the stars and on the scale but may be applied to the quantity $\frac{1}{2}m$ directly; for let us put

$2R =$ reading on Line 65, *minus* reading on Line 70. *minus* $10.^{r}0000$.

Dividing by 2 we obtain R, the quantity given in Table II; we must then add to $\frac{1}{2}m$ the correction

$$-\left(\tfrac{1}{2}m\right)\frac{R}{5} \text{ millimetres.}$$

This correction may conveniently be combined with the correction for non-periodic errors of the screw or variations in its pitch; investigation showed that the following quantities must be added to observed readings of the micrometer head in order to reduce them to what they would have been had the screw been of uniform pitch, but of the same total length:

Reading of the Micrometer Head.	Correction in Millimetres.
r	
5.0	0.
6.0	+ 0.0005
7.0	+ 0.0002
8.0	− 0.0003
9.0	− 0.0012
10.0	− 0.0017
11.0	− 0.0022
12.0	− 0.0021
13.0	− 0.0022
14.0	− 0.0014
15.0	0.

The screw is actually longer than ten turns, but as only this length was used in the determination of the error of runs the rest of the screw was not investigated. It will be observed that the corrections progress uniformly in the interval from $9.^{r}0$ to $11.^{r}0$; advantage was taken of this fact to make the application of the corrections a simple matter. For if the micrometer head be set at $9.^{r}0$ when the microscope is pointed at a star, then the reading on the scale will lie between $9.^{\mathrm{r}}0$ and $11.^{\mathrm{r}}0$ because a whole space of the scale corresponds to two turns of the micrometer head; consequently the correction to the difference of the readings on scale and star will be proportionate to that difference, that is to $\frac{1}{2}\,m$; the correction to the latter is easily seen to be

$$-\left(\tfrac{1}{2}\,m\right) \times 0.0010 \text{ millimetres.}$$

Adding this to the correction for runs we obtain

$$-\left(\tfrac{1}{2}\,m\right)\left(0.00010 + \frac{R}{5}\right) \text{ millimetres.}$$

As an example let us correct the first observation given on the specimen sheet on page 199. The date being March 25, we get from Table II,

$$R = +\,0.0045.$$

Consequently the correction for runs and screw errors is

$$-\left(\tfrac{1}{2}\,m\right) \times 0.0019 \text{ millimetres.}$$

A table may now be constructed with the argument $\frac{1}{2}\,m$ which applies to all observations taken on March 25.

$\frac{1}{2}\,m$.	Correction
0.0	0.0000 millimetres.
0.1	— 0.0002
0.2	— 0.0004
0.3	— 0.0006
0.4	— 0.0008
0.5	— 0.0010
0.6	— 0.0011
0.7	— 0.0013
0.8	— 0.0015
0.9	— 0.0017
1.0	— 0.0019

For the star given on the specimen sheet the correction is — 0.0009. During the second half of each morning's observations when the micrometer head is set at $9.^{\mathrm{r}}5$ instead of at $9.^{\mathrm{r}}0$ it sometimes happens that the reading on the scale exceeds $11.^{\mathrm{r}}0$, in which case the correction will not be exactly proportionate to $\frac{1}{2}\,m$; but the error committed by using the same table throughout will never reach $0.''02$, and in most cases is entirely negligible.

3°. Having applied the corrections given above we have now to change the measures into rectangular coördinates x and y, referred to the central star 15 as origin, one axis being parallel to the cylinder and the other at right angles to it. For this purpose we subtract the mean of all the readings on the central star for any one day from the readings of all the other stars that were measured on that day. As we wish to have positive values of x for those stars which have greater right ascensions than the central star, we must subtract the reading "x direct" from the reading on Star 15; but we must subtract the reading on Star 15 from the reading "x reversed." Similiarly to get positive values of y for those stars having greater declinations than the central star, we subtract the reading on Star 15 from each "y direct" and the contrary for "y reversed."

4° *Rotation Corrections.*

It was found very difficult to set the circle at exactly 90° plus the reading for the previous day. Even when this had been accomplished the circle-reading was sometimes found to have changed a little during the measurement of the stars. A correction is therefore necessary to reduce the rectangular coördinates to what they would have been had the readings of the circle for different days differed only by multiples of 90°. Let

$Q =$ the number of seconds which occurs most often in the circle readings of a particular plate.

$Q - i =$ the number of seconds in the reading for any day.

Then we have,*

Correction for $x = -y.\, i \sin 1.''$
" " $y = +x.\, i \sin 1.''$

For the present measurements these corrections are very small, never exceeding $0.''05$; they have however been applied throughout.

The values of Q adopted for the various plates are as follows:

Plate	I	$Q = 5''$
	II	0
	III	0
	IV	58
	V	7
	VII	0
	VIII	29
	IX	2

5° *Scale-value corrections.*

The scale being made of German silver has a greater coefficient of expansion than the glass plate, and hence it would appear that if the temperature changed during the measurement of a plate, the coördinates would require a correction to reduce them to what they would have been had the temperature remained constant. Investigation shows, however, that such a correction is unnecessary by reason of its minuteness, at least within the limits of the range of temperature at which the present plates were measured. To ascertain the amount of the correction, two well defined specks, such as may be found in the film of any plate, were selected, one near either edge of the plate, and the distance between them was measured at various temperatures. On the morning of April 30, 1897, this distance was measured six times each by Mr. Kretz and myself with the following results:

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* "Permanence of the Rutherfurd Photographic Plates" by Harold Jacoby, Annals of the N. Y. Acad. of Sciences, Vol. IX, p. 267.

	Schlesinger	Kretz:
	104.1548 *mm.*	104.1505 *mm.*
	67	514
	36	505
	30	497
	50	540
	25	517
Mean,	104.1543	104.1513
Probable Error,	± 0.00042	±0.00041

The temperature of the measuring room had been kept at 69.°3 during the measurement by means of artificial heat, the heating apparatus being at the other end of the room from that occupied by the measuring machine. The heat was now turned off and the plate allowed to assume the natural temperature of the atmosphere; on the afternoon of the same day, three hours having elapsed since the first series was completed, the distance between the specks was again measured by the same observers as follows:

	Schlesinger	Kretz
	104.1550 *mm.*	104.1557 *mm.*
	70	44
	63	48
	87	60
	90	53
	70	75
Mean,	104.1572	104.1556
Probable Error,	±0.00041	±.00031

The temperature for this series was 52.°2. Denoting by v the increase in the measured distance due to an increase of 1° in the temperature we have

Schlesinger:	**Kretz:**
$v = -0.00017$ *mm.*	$v = -0.00025$ *mm.*
± 0.000034	± 0.000030

These two values are not very accordant, but they agree sufficiently well for present purposes. As, however, some doubts were entertained as to whether the plates had been thoroughly cooled in the intervening three hours, and as to whether it would not be better to measure the distance between the specks at a season when artificial heat could be entirely dispensed with, the following third series of observations was undertaken by myself, several days elapsing between the various measurements. No artificial heat was allowed in the measuring room during the whole period.

May 20, 1897. Temperature = 73.°6.
104.1530 *mm.*
10
18
30
58
48
25
68

Mean, 104.1536 ± 0.00047

May 22, 1897. Temperature = 69.°6.
104.1534 *mm.*
36
26
44
34
39
54
76

Mean, 104.1543 ± 0.00036

May 29, 1897. Temperature = 71.°0.
104.1548 *mm.*
26
28
64
34
28
36
34

Mean, 104.1537 ± 0.00031

July 27, 1897. Temperature = 82.°1.

104.1532 *mm.*
525
505
530
520
495
510
542
510
522
548
525

Mean, 104.1522 ± 0.00031

Denoting by v as before the increase in the distance due to an increase of 1° in the temperature, and by L the distance between the specks at the temperature 69.°6 we have the following four observation equations:

$$\begin{array}{lll} L - 104.1543 = 0 & \text{weight} & 3 \\ L + 1.4\,v - 104.1537 = 0 & \text{"} & 5 \\ L + 4.0\,v - 104.1536 = 0 & \text{"} & 2 \\ L + 12.5\,v - 104.1522 = 0 & \text{"} & 5 \end{array}$$

The weights are calculated from the probable errors given above, the probable error of an equation of weight unity being

± 0.00067

Solving by least squares we get

$$v = -0.00015 \pm 0.000032$$

Taking into account the two previous series, the mean by weight is

$$v = -0.00019 \; mm.$$

which very probably does not differ from its true value by as much as 0.00005.

Now the largest coördinate in the Præsepe measures is less than forty millimetres, and the greatest deviation for any single day from the mean of the temperatures for the corresponding plate is less than 5°; consequently the largest correction which it will ever be necessary to apply is

0.00037 *mm.*

which corresponds to 0.″02. As this is so small, even in the extreme case, no appreciable error will be committed by neglecting the correction altogether. We may indeed conclude that for the scale under consideration and for the Rutherfurd plates, a correction for change in the scale-value will be unnecessary so long as the temperature does not vary more than 10° during the measurement of a single plate.

6° *Projection Errors* and *Deviation of the Cylinder from Straightness.*

In the present work corrections have been applied for neither of these; the first were discussed by Donner * and are very small in most cases; it is indeed very difficult to determine them with sufficient accuracy. Repsold has recently devised a new guiding way which is free from this source of error; the measuring machine used for the Præsepe plates had been furnished with such a guiding way in 1896. As regards the straightness of the cylinder, investigation showed that it had been admirably made †; the greatest error which we shall commit in assuming it to be straight is 0.″04; the reversal of each plate and the insertion of different plates in different positions in the measuring machine will tend to eliminate even this small error.

Having now completed the consideration of all the instrumental corrections which it is necessary to apply, I shall conclude this subject by correcting the measurements of Star 7, Plate VIII, as given on page 199, or in Table III.

	March 25, x direct	March 24, y direct:	March 18, x reversed:	March 22, y reversed:
Lines, ...	74,76	36	43,44	83
$\frac{1}{2}m$; First obs'v'r.,..	0.4646	— 0.0154	0.5938	0.5680
Second " ..	0.4639	— 0.0178	0.5896	0.5670
Mean,.............	0.4643	— 0.0166	0.5917	0.5675
Cor. for Runs, etc.,	— 9	0	— 11	— 11
Div. Correction, ...	+ 50	+ 24	+ 26	+ 50
Corrected $\frac{1}{2}m$, ...	0.4684	— 0.0142	0.5932	0.5714
Measurement, ...	75.4684	35.9858	44.0932	83.5714

Where two lines have been used the division correction is the mean of the division corrections for the separate lines; the final "measurement" is then obtained by adding the mean of the numbers of the lines to the corrected $\frac{1}{2}$ *m*. The corresponding measurements for the central star 15 when similiarly corrected are:

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* "Détermination des Constantes nécessaires pour la Reduction des Clichés." Acta Societatis Scientiarum Fennicae, Vol. XXI.

† "Permanence of the Rutherfurd Plates" by Harold Jacoby; Annals of the N. Y. Acad. of Sciences, Vol. IX, page 210.

	March 25, x direct:	March 24, y direct:	March 18, x reversed	March 22, y reversed
	60.7692	55.0133	58.7883	64.5497
	7695	0104	7887	5457
	7731	0100	7870	5448
	7712	0123	7871	5450
Mean,	60.7708	55.0115	58.7878	64.5463

Taking the differences between these and the corresponding measurements for Star 7, having regard to signs, we get:

Coördinates,........	—14.6976	—19 0257	—14 6946	—19 0251
Rotation Cor.,......	0	+ 4	+ 2	0
Final Coörd.,......	—14.6976	—19.0253	—14.6944	—19.0251

These are the quantities given in Table V, which needs no further explanation. In comparing the direct with the reversed coördinates, it should be remembered that unity in the fourth decimal place corresponds to about 0.″005 of arc of a great circle.

TABLE V.—CORRECTED COÖRDINATES. PLATE I.

Star.	*x*			*y*		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—34.5052	.5028	—34.5040	+15.6854	.6850	+15.6852
2	—33.5104	.5082	—33.5093	— 3.4200	.4188	— 3.4194
3	—32.3942	.3922	—32.3932	—18.0042	.0055	—18.0049
4	—30.6393	.6348	—30.6370	—35.0918	.0906	—35.0912
5	—21.6168	.6161	—21.6165	+28.9521	.9571	+28.9546
6	—17.4281	.4236	—17.4258	+14.2048	.2048	+14.2048
7	—14.6839	.6843	—14.6841	—19.0394	.0412	—19.0403
8	—10.5876	.5849	—10.5862	+14.9500	.9500	+14.9500
10	— 9 6888	.6886	— 9.6887	— 7.0204	.0201	— 7.0203
11	— 8.8264	.8270	— 8.8267	—12.7576	.7577	—12.7576
14	— 0.2020	.2022	— 0.2021	+20.9438	.9455	+20.9446
15	0.0000	.0000	0.0000	0.0000	.0000	0.0000
16	+ 0.9159	.9173	+ 0.9166	—34.2424	.2429	—34.2426
17	+ 2.3272	.3293	+ 2.3283	—16.1534	.1504	—16.1519
18	+ 3.8697	.8712	+ 3.8705	—15.3037	.3022	—15.3030
20	+ 4.2144	.2182	+ 4.2163	—16.0818	.0826	—16.0822
22	+ 6.1437	.1546	+ 6.1541	+15.6744	.6760	+15.6752
23	+ 7.5258	.5276	+ 7.5267	+13.2000	.2000	+13.2000
23A	+ 8.5446	.5478	+ 8.5462	+14.7914	.7874	+14.7894
24	+ 9.6569	.6587	+ 9.6578	—16 6650	.6664	—16.6657
25	+10.2385	.2420	+10.2402	— 6.1255	.1240	— 6.1248
26	+10.3560	.3580	+10.3570	—29.1131	.1110	—29.1120
27	+10.6100	.6095	+10.6098	— 7.2644	.2646	— 7.2645
28	+10.8422	.8406	+10.8414	+ 3.9756	.9756	+ 3.9756
29	+11.4264	.4272	+11.4268	+27.6000	.5983	+27.5992
31	+12.0292	.0308	+12.0300	—15.7662	.7623	—15.7642
32	+13 9115	.9104	+13.9110	—39 5974	.5944	—39.5959
33	+15.5667	.5705	+15.5686	—37.2662	.2662	—37.2662
34	+16.2032	.2048	+16.2040	— 3.8424	.8368	— 3.8396
35	+18.1994	.1978	+18.1986	+33.4348	.4344	+33.4346
36	+19.6786	.6824	+19.6805	+10.8790	.8794	+10.8792
37	+19.8224	.8254	+19.8239	—13.2516	.2506	—13 2512
38	+23.4340	.4385	+23.4362	+ 3.7612	.7620	+ 3.7616
39	+24.1815	.1872	+24.1844	+10.0636	.0626	+10.0631
40	+26.0190	.0207	+26.0198	—34.9100	.9092	—34.9096
43	+33.9119	.9091	+33.9105	+ 6.9450	.9450	+ 6.9450
44	+34.4409	.4470	+34 4440	+26.3683	.3666	+26.3674

TABLE V.—(*Continued.*) CORRECTED COÖRDINATES. PLATE II.

Star.	*x*			*y*		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—34.5040	.5037	—34.5038	+15.6928	.6954	+15.6941
2	—33.5044	.5036	—33.5040	— 3.4064	.4061	— 3.4062
4	—30.6440	.6420	—30.6430	—35.0756	.0789	—35.0772
5	—21.6032	.6037	—21.6035	+28.9578	.9610	+28.9594
6	—17.4227	.4214	—17.4221	+14.2064	.2055	+14.2059
7	—14.6867	.6812	—14 6840	—19.0368	.0348	—19.0358
7A	—10.5894	.5874	—10.5884	— 3.7603	.7585	— 3.7594
8	—10.5806	.5799	—10.5803	+14.9550	.9538	+14.9544
10	— 9.6862	.6838	— 9.6850	— 7.0164	.0154	— 7.0159
11	— 8.8272	.8259	— 8.8266	—12.7520	.7530	—12.7525
14	— 0.2004	.2006	— 0 2005	+20.9444	.9442	+20.9443
15	0.0000	.0000	0.0000	0.0000	.0000	0.0000
16	+ 0.9121	.9122	+ 0.9122	—34.2378	.2359	—34.2368
17	+ 2.3210	.3230	+ 2.3220	16.1492	.1480	—16.1486
18	+ 3.8660	.8664	+ 3.8662	—15.3018	.3032	—15.3025
19	+ 3.8978	.8967	+ 3.8972	+25.8933	.8950	+25.8942
20	+ 4.2114	.2147	+ 4 2130	—16.0802	.0786	—16.0794
22	+ 6.1538	.1518	+ 6.1528	+13.1972	.1972	+13.1972
23A	+ 8.5476	.5505	+ 8 5490	+14.7833	.7834	+14.7834
24	+ 9.6502	.6500	+ 9 6501	—16 6680	.6658	—16 6669
25	+10.2337	.2350	+10.2344	— 6.1280	.1255	— 6.1268
26	+10.3454	.3492	+10 3473	—29.1082	.1090	—29.1086
27	+10.6000	.6032	+10 6016	— 7.2620	.2598	— 7.2609
28	+10.8382	.8390	+10.8386	+ 3.9732	.9757	+ 3.9744
29	+11.4256	.4253	+11.4254	+27.5944	.5926	+27.5935
31	+12.0266	.0287	+12.0276	—15.7620	.7641	—15.7630
32	+13.9074	.9049	+13.9061	—39.5946	.5894	—39.5920
33	+15.5584	.5616	+15.5600	—37.2621	.2607	—37.2614
34	+16.2032	.2031	+16.2031	— 3.8444	.8394	— 3.8419
35	+18.2036	.2038	+18.2037	+33.4284	.4314	+33.4299
36	+19.6828	.6814	+19.6821	+10.8745	.8752	+10.8749
37	+19.8174	.8190	+19 8182	—13.2498	.2495	—13.2496
38	+23.4373	.4378	+23.4375	+ 3.7584	.7606	+ 3.7595
39	+24.1793	.1830	+24.1812	+10.0571	.0604	+10.0587
40	+26.0170	.0153	+26.0162	—34.9106	.9091	—34.9098
43	+33.9056	.9042	+33.9049	6.9342	.9360	+ 6.9351
44	+34.4474	.4480	+34.4477	+26.3596	.3632	+26.3614
45	+38.7409	.7417	+38.7413	—24.5064	.5066	—24.5065

TABLE V.—(*Continued.*) CORRECTED COÖRDINATES. PLATE III.

Star	x			y		
	Direct.	Rev'd.	Mean	Direct	Rev'd	Mean.
1	—34 4942	.4942	—34.4942	+15.7075	.7076	+15.7076
2	—33.5073	.5094	—33.5084	— 3.3957	.3940	— 3.3948
3	—32.4044	.4030	—32.4037	—17.9840	.9844	—17.9842
4	—30.6587	.6538	—30.6562	—35.0679	.0660	—35.0670
5	—21.5902	.5939	—21.5920	+ 28.9642	.9662	+28.9652
6	—17.4130	.4134	—17.4132	+14.2124	.2157	+14.2141
7	—14.6935	.6974	—14.6954	—19.0312	.0342	—19.0327
8	—10.5682	.5685	—10.5684	+14.9584	.9602	+14 9593
10	— 9 6864	.6859	— 9 6862	— 7.0159	.0138	— 7.0148
11	— 8.8284	.8312	— 8.8298	—12.7523	.7510	—12.7517
14	— 0.1866	.1878	— 0.1872	+20.9390	.9420	+20.9405
15	0.0000	.0000	0.0000	0.0000	.0000	0.0000
16	+ 0.8979	.8959	+ 0.8969	—34.2431	.2410	—34.2420
17	+ 2.3194	.3190	+ 2.3192	—16.1527	.1504	—16.1516
18	+ 3.8596	.8590	+ 3.8593	—15.3089	.3060	—15.3074
20	+ 4.2056	.2076	+ 4.2066	—16.0852	.0818	—16 0835
22	+ 6.1663	.1653	+ 6.1658	+15.6676	.6737	+15.6706
23	+ 7.5299	.5297	+ 7.5298	+13 1907	.1931	+13.1919
23A	+ 8.5566	.5554	+ 8.5560	+14.7819	.7820	+14.7820
24	+ 9.6504	.6490	+ 9.6497	—16.6740	.6688	—16.6714
25	+10.2314	.2295	+10.2305	— 6.1371	.1310	— 6.1340
26	+10.3361	.3369	+10.3365	—29 1205	.1154	—29 1180
27	+10.6036	.6032	+10 6034	— 7.2689	.2712	— 7.2700
28	+10.8441	.8452	+10.8447	+ 3.9637	.9659	+ 3.9648
29	+11.4440	.4462	+11.4451	+27.5865	.5912	+27.5888
31	+12.0134	.0165	+12.0150	—15.7675	.7700	—15.7688
32	+13.8892	.8889	+13.8891	—39.6008	.6048	—39 6028
33	+15.5390	.5422	+15.5406	—37.2750	.2731	—37.2740
34	+16.2035	.2034	+16.2034	— 3 8514	.8503	— 3.8508
35	+18.2207	.2234	+18.2221	+33 4219	.4217	+33.4218
36	+19.6910	.6868	+19.6889	+10.8652	.8620	+10.8636
37	+19.8112	.8124	+19.8118	—13.2630	.2656	—13.2643
39	+24.1897	.1879	+24.1888	+10.0472	.0462	+10.0467
40	+25.9978	.0012	+25.9995	—34.9216	.9212	—34.9214
43	+33.9138	.9114	+33.9126	+ 6.9199	.9170	+ 6.9184
44	+34.4648	.4650	+34.4649	+26.3452	.3448	+26.3450
45	+38.7302	.7281	+38.7292	—24.5248	.5266	—24.5257

TABLE V.—(*Continued.*) CORRECTED COÖRDINATES. PLATE IV.

Star.	*x*			*y*		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—34.5081	.5005	—34.5043	+15.6765	.6747	+15.6756
2	—33.5014	.4986	—33.5000	— 3.4249	.4234	— 3.4241
3	—32.3816	.3810	—32.3813	—18.0095	.0107	—18.0101
4	—30.6188	.6162	—30.6175	—35.0890	.0904	—35.0897
5	—21.6262	.6230	—21.6246	+28.9437	.9424	+28.9430
6	—17.4268	.4245	—17.4256	+14.1982	.2015	+14.1999
7	—14.6724	.6690	—14.6707	—19.0377	.0411	—19.0394
7A	—10.5836	.5818	—10.5827	— 3.7664	.7693	— 3.7678
8	—10.5906	.5902	—10.5904	+14.9470	.9494	+14.9482
10	— 9.6824	.6814	— 9.6819	— 7.0229	.0209	— 7.0219
11	— 8.8172	.8155	— 8.8164	—12.7601	.7583	—12.7592
14	— 0.2114	.2107	— 0.2110	+20.9386	.9403	+20.9394
15	0.0000	.0000	0.0000	0.0000	.0000	0.0000
16	+ 0.9326	.9340	+ 0.9333	—34.2394	.2372	—34.2383
17	+ 2.3349	.3362	+ 2.3356	—16.1490	.1489	—16.1490
18	+ 3.8712	.8732	+ 3.8722	—15.3017	.3015	—15.3016
19	+ 3.8816	.8832	+ 3.8824	+25.8905	.8886	+25.8896
20	+ 4.2190	.2192	+ 4.2191	—16.0778	.0775	—16.0777
22	+ 6.1440	.1465	+ 6.1452	+15.6732	.6741	+15.6737
23	+ 7.5157	.5178	+ 7.5168	+13.1976	.1967	+13.1971
23A	+ 8.5374	.5399	+ 8.5387	+14.7866	.7864	+14.7865
24	+ 9.6622	.6640	+ 9.6631	—16.6652	.6606	—16.6629
25	+10.2376	.2372	+10.2374	— 6.1234	.1220	— 6.1227
26	+10.3627	.3652	+10.3639	—29.1068	.1060	—29.1064
27	+10.6071	.6077	+10.6074	— 7.2612	.2614	— 7.2613
28	+10.8355	.8374	+10.8364	+ 3.9759	.9771	+ 3.9765
29	+11.4120	.4129	+11.4124	+27.5930	.5960	+27.5945
31	+12.0288	.0305	+12.0297	—15.7623	.7610	—15.7616
32	+13.9279	.9289	+13.9284	—39.5870	.5883	—39.5876
33	+15.5832	.5771	+15.5802	—37.2559	.2551	—37.2555
34	+16.2028	.2030	+16.2029	— 3.8344	.8350	— 3.8347
35	+18.1752	.1798	+18.1775	+33.4338	.4318	+33.4328
36	+19.6722	.6738	+19.6730	+10.8808	.8800	+10.8804
37	+19.8242	.8250	+19.8246	—13.2450	.2459	—13.2454
38	+23.4288	.4324	+23.4306	+ 3.7647	.7636	+ 3.7642
39	+24.1717	.1728	+24.1722	+10.0655	.0655	+10.0655
40	+26.0288	.0312	+26.0300	—34.8968	.8938	—34.8953
43	+33.8955	.8986	+33.8970	+ 6.9446	.9455	+ 6.9450
44	+34.4188	.4232	+34.4210	+26.3714	.3697	+26.3706
45	+38.7495	.7503	+38.7499	—24.4909	.4900	—24.4904

TABLE V.—(*Continued.*) CORRECTED COÖRDINATES. PLATE V.

Star.	*x*			*y*		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—34.4912	.4900	—34.4906	+15.7164	.7130	+15.7147
2	—33.5065	.5062	—33.5064	— 3.3860	.3897	— 3.3878
3	—32.4083	.4072	—32.4077	—17.9751	.9772	—17.9762
4	—30.6656	.6644	—30.6650	—35.0600	.0620	—35.0610
5	—21.5824	.5810	—21.5817	+28.9692	.9680	+28.9686
6	—17.4077	.4090	—17.4084	+14.2193	.2187	+14.2190
7	—14.6985	.6980	—14.6982	—19.0254	.0321	—19.0288
8	—10.5690	.5682	—10.5686	+14.9581	.9598	+14.9589
10	— 9.6874	.6894	— 9.6884	— 7.0102	.0116	— 7.0109
11	— 8.8342	.8320	— 8.8331	—12.7484	.7500	—12.7492
14	— 0.1788	.1805	— 0.1797	+20.9386	.9374	+20.9380
15	0.0000	.0000	0.0000	0.0000	.0000	0.0000
16	+ 0.8868	.8872	+ 0.8870	—34.2418	.2394	—34.2406
17	+ 2.3130	.3152	+ 2 3141	—16.1528	.1520	—16.1524
18	+ 3.8581	.8571	+ 3.8576	—15.3042	.3044	—15.3043
19	+ 3.9180	.9201	+ 3.9190	+25.8858	.8814	+25.8836
20	+ 4.2016	.2034	+ 4.2025	—16.0850	.0826	—16.0838
22	+ 6.1697	.1684	+ 6.1690	+15.6671	.6672	+15.6672
23	+ 7.5392	.5374	+ 7.5383	+13.1906	.1916	+13.1911
23A	+ 8.5584	.5599	+ 8.5592	+14.7780	.7756	+14.7768
24	+ 9.6428	.6431	+ 9.6429	—16.6726	.6745	—16.6736
25	+10.2291	.2308	+10.2299	— 6.1376	.1352	— 6.1364
26	+10.3236	.3257	+10.3246	—29.1198	.1210	—29.1204
27	+10.6022	.6037	+10 6030	— 7.2723	.2700	— 7.2711
28	+10.8461	.8451	+10.8456	+ 3.9626	.9622	+ 3.9624
29	+11.4492	.4498	+11.4495	+27.5812	.5812	+27.5812
31	+12.0096	.0100	+12.0098	—15.7728	.7723	—15.7726
32	+13.8710	.8778	+13.8744	—39.6013	.6038	—39.6025
34	+16.1957	.1977	+16.1967	— 3.8561	.8526	— 3.8543
35	+18.2316	.2267	+18.2292	+33.4117	.4098	+33.4108
37	+19.8083	.8070	+19.8077	—13.2664	.2697	—13.2680
39	+24.1869	.1882	+24.1876	+10.0364	.0376	+10.0370
40	+25.9806	.9837	+25.9822	—34 9250	.9260	—34.9255
43	+33.9056	.9072	+ 33.9064	+ 6.9073	.9062	+ 6 9068
44	+34.4653	.4661	+ 34.4657	+26.3334	.3336	+26.3335
45	+38.7196	.7170	+38.7183	—24.5324	.5328	—24 5326

TABLE V.—(*Continued.*) CORRECTED COÖRDINATES. PLATE VII.

Star.	*x*			*y*		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—34.4817	.4843	—34.4830	+15.7221	.7231	+15.7226
2	—33.5043	.5043	—33.5043	— 3.3759	.3763	— 3.3761
3	—32.4086	.4100	—32.4093	—17.9669	.9658	—17.9664
4	—30.6694	.6673	—30.6684	—35.0474	.0472	—35.0473
5	—21.5742	.5714	—21.5728	+28.9724	.9737	+28.9730
6	—17.4069	.4056	—17.4062	+14.2230	.2216	+14.2223
7	—14.7014	.7022	—14.7018	—19.0236	.0206	—19.0221
7A	—10.5922	.5894	—10.5908	— 3.7542	.7547	— 3.7545
8	—10.5673	.5687	—10.5680	+14.9603	.9586	+14.9595
10	— 9.6920	.6904	— 9.6912	— 7.0050	.0060	— 7.0055
11	— 8.8388	.8402	— 8.8395	—12.7439	.7446	—12.7443
14	— 0.1793	.1816	— 0.1805	+20.9396	.9388	+20.9392
15	0.0000	.0000	0.0000	0.0000	.0000	0.0000
16	+ 0.8806	.8805	+ 0.8806	—34.2354	.2364	—34.2359
17	+ 2.3125	.3090	+ 2.3108	—16.1506	.1493	—16.1500
18	+ 3.8524	.8514	+ 3.8519	—15.3052	.3057	—15.3054
19	+ 3.9198	.9222	+ 3.9210	+25.8832	.8854	+25.8843
20	+ 4.1979	.1962	+ 4.1971	—16.0844	.0854	—16.0849
21	+ 4.7178	.7213	+ 4.7196	+24.3594	.3554	+24.3574
22	+ 6.1656	.1624	+ 6.1640	+15.6664	.6633	+15.6648
23	+ 7.5330	.5340	+ 7.5335	+13.1890	.1872	+13.1881
23A	+ 8.5558	.5590	+ 8.5574	+14.7731	.7745	+14.7738
24	+ 9.6320	.6332	+ 9.6326	—16.6755	.6736	—16.6745
25	+10.2276	.2252	+10.2264	— 6.1370	.1348	— 6.1359
26	+10.3185	.3214	+10.3199	—29.1174	.1180	—29.1177
27	+10.5986	.5979	+10.5982	— 7.2726	.2710	— 7.2718
28	+10.8415	.8406	+10.8410	+ 3.9608	.9590	+ 3.9599
29	+11.4500	.4474	+11.4487	+27.5814	.5797	+27.5806
31	+12.0062	.0064	+12.0063	—15.7710	.7727	—15.7718
32	+13.8671	.8658	+13.8664	—39.6006	.6022	—39.6014
33	+15.5207	.5220	+15.5214	—37.2730	.2721	—37.2726
34	+16.1972	.1980	+16.1976	— 3.8560	.8536	— 3.8548
35	+18.2277	.2290	+18.2284	+33.4081	.4088	+33.4084
36	+19.6808	.6854	+19.6831	+10.8540	.8588	+10.8564
37	+19.8020	.8021	+19.8020	—13.2730	.2723	—13.2726
38	+23.4334	.4379	+23.4356	+ 3.7330	.7316	+ 3.7323
39	+24.1835	.1831	+24.1833	+10.0310	.0340	+10.0325
40	+25.9716	.9742	+25.9729	—34.9286	.9282	—34.9284
41	+30.0359	.0402	+30.0381	— 7.5610	.5599	— 7.5605
42	+32.0193	.0197	+32.0195	— 7.6587	.6003	— 7.6595
43	+33.9009	.9016	+33.9012	+ 6.8994	.9014	+ 6.9004
44	+34.4624	.4636	+34.4630	+26.3208	.3246	+26.3227
45	+38.7094	.7085	+38.7090	—24.5388	.5361	—24.5374

TABLE V.—(*Continued.*) CORRECTED COÖRDINATES. PLATE VIII.

Star.	*x*			*y*		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—34.4857	.4866	—34.4862	+15.7100	.7124	+15.7112
2	—33.5032	.5024	—33.5028	— 3.3848	.3846	— 3.3847
3	—32.4060	.4011	—32.4036	—17.9734	.9738	—17.9736
4	—30.6600	.6560	—30.6580	—35.0517	.0524	—35.0520
5	—21.5811	.5808	—21.5809	+28.9670	.9680	+ 28.9675
6	—17.4127	.4101	—17.4114	+14.2171	.2192	+14.2182
7	—14.6976	.6944	—14.6960	—19.0253	.0251	—19.0252
7A	—10.5962	.5969	—10.5966	— 3.7603	.7626	— 3.7615
8	—10.5749	.5718	—10.5733	+14.9556	.9570	+14.9563
10	— 9.6885	.6880	— 9.6882	— 7.0098	.0096	— 7.0097
11	— 8.8362	.8352	— 8.8357	—12.7488	.7488	—12.7488
14	— 0.1844	.1852	— 0.1848	+20.9374	.9392	+20.9383
15	0.0000	.0000	0.0000	0.0000	.0000	0.0000
16	+ 0.8857	.8885	+ 0.8871	—34.2371	.2353	—34.2362
17	+ 2.3126	.3134	+ 2.3130	—16.1488	.1500	—16.1494
18	+ 3.8562	.8560	+ 3.8561	—15.3028	.3060	—15.3044
19	+ 3.9104	.9097	+ 3.9100	+25.8812	.8832	+25.8822
20	+ 4.2000	.2031	+ 4.2016	—16.0818	.0820	—16.0819
22	+ 6.1610	.1636	+ 6.1623	+15.6656	.6687	+15.6672
23	+ 7.5284	.5337	+ 7.5310	+13.1874	.1886	+13.1880
23A	+ 8.5506	.5521	+ 8.5513	+ 14.7729	.7760	+14.7744
24	+ 9.6418	.6438	+ 9.6428	—16.6723	.6726	—16.6724
25	+10.2268	.2256	+10.2262	— 6.1372	.1347	— 6.1360
26	+10.3278	.3292	+10.3285	—29.1152	.1163	—29.1158
27	+10.5974	.5974	+10.5974	— 7.2728	.2689	— 7.2708
28	+10.8416	.8408	+10.8412	+ 3.9608	.9648	+ 3.9628
29	+11.4424	.4426	+11.4425	+ 27.5784	.5800	+ 27.5792
31	+12.0110	.0137	+12.0124	—15.7707	.7748	—15.7727
32	+13.8756	.8780	+13.8768	—39.6012	.6014	—39.6013
33	+15.5298	.5320	+15.5309	—37.2751	.2712	—37.2732
34	+16.1969	.1962	+16.1966	— 3.8543	.8544	— 3.8544
35	+18.2171	.2166	+18.2168	+33.4060	.4086	+33.4073
36	+19.6751	.6778	+19.6764	+10.8545	.8562	+10.8554
37	+19.8014	.8057	+19.8035	—13.2662	.2670	—13.2666
38	+23.4306	.4318	+23.4312	+ 3.7362	.7382	+ 3.7372
39	+24.1790	.1761	+24.1776	+10.0346	.0351	+10.0348
40	+25.9807	.9800	+25.9804	—34.9247	.9232	—34.9240
41	+30.0339	.0342	+30.0340	— 7.5534	.5538	— 7.5536
42	+32.0097	.0144	+ 32.0120	— 7.6577	.6576	— 7.6576
43	+33.8966	.8960	+33.8963	+ 6.9064	.9093	+ 6.9079
44	+34.4516	.4494	+34.4505	+26.3255	.3264	+26.3259
45	+38.7120	.7129	+38.7124	—24.5322	.5326	—24.5324

TABLE V.—(*Concluded.*) CORRECTED COÖRDINATES. PLATE IX.

Star.	*x*			*y*		
	Direct.	Rev'd	Mean.	Direct	Rev'd.	Mean
1	—34 4800	.4842	—34.4821	+15.7316	.7334	+15.7325
2	—33.5050	.5025	—33 5037	— 3.3680	.3664	— 3.3672
3	—32.4120	.4079	—32.4100	—17.9574	.9570	—17.9572
4	—30 6766	.6746	—30 6756	—35.0392	0384	—35.0388
5	—21.5667	.5659	--21.5663	+28.9755	.9802	+28 9778
6	—17.4034	.4030	—17.4032	+14 2269	.2304	+14 2286
7	—14.7092	.7056	—14.7074	—19.0220	.0194	—19.0208
8	—10 5617	.5612	—10.5614	+14.9613	.9682	+14.9648
10	— 9.6866	.6860 .	— 9.6863	— 7.0064	.0018	— 7.0041
11	— 8.8444	8424	— 8.8434	—12.7406	.7372	—12.7389
14	— 0 1718	.1718	— 0.1718	+20 9388	.9407	+20 9397
15	0.0000	.0000	0.0000	0 0000	.0000	0.0000
16	+ 0.8652	.8684	+ 0.8668	—34.2368	.2330	—34.2349
17	+ 2.3019	.3048	+ 2.3033	—16.1486	.1504	—16.1495
18	+ 3.8459	.8481	+ 3.8470	—15.3053	.3054	—15.3054
20	+ 4.1952	.1981	+ 4.1966	--16.0804	.0809	—16 0807
22	+ 6.1756	.1759	+ 6.1758	+15.6626	.6655	+15.6640
23	+ 7.5408	.5429	+ 7.5418	+13.1893	.1902	+13.1898
23A	+ 8.5656	.5620	+ 8.5638	+14.7698	.7735	+14.7716
24	+ 9 6386	6369	+ 9.6378	—16.6742	.6750	—16 6746
25	+10.2299	2300	+10.2300	— 6 1412	1352	— 6.1382
26	+10.3108	.3114	+10.3111	—29.1168	.1175	—29 1171
27	+10.5979	.5991	+10.5985	— 7.2740	.2707	— 7.2724
28	+10 8479	.8466	+10.8473	+ 3.9552	.9610	+ 3.9581
29	+11.4602	.4605	+11.4603	+27 5766	.5815	+27.5790
31	+12.0046	.0050	+12.0048	—15.7726	.7764	—15.7745
32	+13 8562	.8568	+13.8565	—39.6046	.6040	—39.6043
33	+15.5071	.5086	+15.5079	—37.2773	.2739	—37.2756
34	+16.1936	.1964	+16.1950	— 3.8618	.8610	— 3.8614
35	+18.2386	.2367	+18.2376	+33.4038	.4042	+33.4040
36	+19 6886	.6863	+19.6875	+10.8493	.8510	+10.8502
37	+19.7985	.8004	+19 7994	—13.2732	.2738	—13.2735
38	+23.4416	.4410	+23.4413	+ 3.7287	.7290	+ 3.7289
39	+24.1886	.1881	+24.1884	+10.0280	.0287	+10.0284
40	+25 9634	.9639	+25.9637	—34.9383	.9338	—34.9360
43	+33.9029	.9006	+33.9018	+ 6.8892	.8907	+ 6.8899
44	+34.4765	.4747	+34.4756	+26.3112	.3123	+26.3117
45	+38.7025	.7012	+38.7018	—24.5497	.5502	—24.5499

IV.

Method of Reduction.

The measured coördinates having been cleared of instrumental errors, it remains to convert them into right ascensions and declinations. For this purpose the following constants must be known for each plate:

1°. The right ascension of the centre of the plate, in this case the central star 15.

2°. The declination of the same star.

3°. The scale-value, or the number of seconds corresponding to one space on the scale.

4°. The orientation correction, or the angle through which we must rotate the coördinate axes in order that they may point respectively in the directions of a parallel of declination and a circle of declination through the central star.

The first plan that suggested itself for determining these constants was to employ the two existing heliometer researches upon the group. In 1856 to 1858 Professor Winnecke of Bonn measured the position angles and distances of forty-four stars from the central star 15; and in 1889 to 1892 Professor Schur of Göttingen triangulated thirty-eight stars and derived the places of seven more by measuring the position angles and distances from stars in the triangulation. The results of both researches were published in one volume by Professor Schur, part IV of the "Astronomische Mittheilungen von der K. Sternwarte zu Göttingen." The stars whose positions are there given include almost all those appearing on the photographs, and consequently very accurate values of the four constants could be obtained by comparing the measured coördinates of a large number of stars with their heliometer places. Another plan is to determine the constants by comparison with meridian observations. While this is not as accurate as the preceding, it has the advantage of being independent of the heliometer results, thus rendering a comparison with the latter more instructive.

The course that I have actually pursued is this: the constants were first determined for each plate separately by comparing the coördinates of some of the stars with meridian observations. For a star which appears on all the plates we have thus eight determinations of its right ascension, and eight of its declination, and a catalogue of the group may now be formed by taking the means. Finally a least square solution was made to determine how much the constants would have to be changed on the average, so as to secure the best possible agreement with the heliometer places. It is evident that if we now apply to our catalogue positions the corrections which result from these average changes in the constants we shall obtain the same results as though we had used the heliometer places to determine the constants for the separate plates, and had then taken the means.

The meridian observations used are those quoted by Professor Schur in the work mentioned above; they were used by him to help fix the place of his triangulation in the sky. Five stars were observed, the central star and four others distributed symmetrically over the plate; they are admirably fitted for our purpose, being at sufficiently large distances from the central star to insure accurate determinations of the scale-value and orientation, and yet not so distant as to have their photographic images much distorted. Their magnitudes are such that they appear on all of the plates with good images. The stars were observed both at Berlin and Göttingen;* the positions obtained at the former observatory and reduced to the A. G. catalogue system are as follows:

Star.	Epoch.	Equinox of 1890.0.	
4	1890.26	$8^h31^m28.^s444$,	$+19^\circ39'00''.65$
5	.51	32 02. 359	20 35 28 .43
15	.26	33 23. 463	20 09 55 .38
40	.51	35 00. 573	19 39 04 .35
44	.26	35 33. 417	20 33 03 .28

Each star was observed four times, and the probable error of a single observation is given as

$\pm 0.^s012$ in right ascension,
$\pm 0.''25$ in declination.

At Göttingen each star was observed six times with these results:

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* "Astronomische Mittheilungen von der K. Sternwarte zu Göttingen," Part IV, pages 139 et seq.

Star.	Epoch.	Equinox of 1890.0.	
4	1891.52	$8^{h}31^{m}$ 28.425,	+19°38′59″.83
5	.37	32 02.388	20 35 27 .75
15	.55	33 23.462	20 09 55 .52
40	.89	35 00.607	19 39 04 .03
44	.89	35 33.447	20 33 03 .40

Giving these observations the weight $\frac{1}{3}$, and those at Berlin the weight unity, as was done by Professor Schur, we get finally:

Star.	Epoch.	Equinox of 1890.0.	
4	1890.58	$8^{h}31^{m}$ 28.440,	+19 39′00″.45
5	.72	32 02.366	20 35 28 .26
15	.58	33 23.463	20 09 55 .42
40	.86	35 00.582	19 39 04 .27
44	.67	35 33.425	20 33 03 .31

As the epochs of these observations are from thirteen to twenty years later than the dates of our plates, it is necessary to apply proper motions, for which the following values have been adopted:

4	$-0.^{s}0054$	+0″.007
5	-0.0005	+0 .038
15	-0.0049	+0 .017
40	-0.0040	+0 .011
44	-0.0044	+0 .015

These are the values given by Professor Schur in his catalogue of the group, but they are not derived directly from a comparison of his places with those of Winnecke. Systematic corrections have been added to make the proper motion of the group as a whole conform with observations by Bradley and by Tobias Mayer; these corrections are:

$-0.^{s}0003$ +0″.039.

The necessity for such a large correction in declination is accounted for by Professor Schur, by assuming that either in the Bonn or in the Göttingen observations, or perhaps in both, the declination of the group as a whole was incorrectly determined; we shall have occasion to refer to this circumstance later.

The plates were taken at practically only two dates, 1870.3 and 1877.3; applying the corresponding proper motions to the meridian observations and reducing them to the equinox of 1875.0, we get:

For Plates I, II, III and IV,

	$\Delta\alpha$	$\Delta\delta$
4	—1723″.34	—1856″.74
5	—1220 .23	+1531 .02
15	0	0
40	+1459 .38	—1849 .36
44	+1948 .13	+1390 .16
	α_0	δ_0
15	128°07′55″.26	+20°13′01″.26

For Plates V, VII, VIII and IX,

	$\Delta\alpha$	$\Delta\delta$
4	—1723″.40	—1856″.81
5	—1219 .75	+1531 .17
15	0	0
40	+1459 .48	—1849 .40
44	+1948 .19	+1390 .15
	α_0	δ_0
15	128°07′51″.75	+20°13′01″.38

$\Delta\alpha$ and $\Delta\delta$ are obtained by subtracting the right ascension and declination of Star 15 from those of the five comparison stars.

The numerical work in the problem before us, namely, to determine the constants of the plates, will be greatly decreased by first assuming an approximate scale-value and then determining how much this is in error. Such an approximate value is furnished by the reduction of Rutherfurd's photographs of the Pleiades where it was found that

1 millimetre = 52.″87

Let us suppose that this scale-value has been applied to the measured coördinates x and y of each of the comparison stars, giving X and Y; then the quantities $X \sec \delta_0$ and Y will be nearly equal to the corresponding $\Delta\alpha$ and $\Delta\delta$ respectively. The causes of difference are the following:

a. Transformation Corrections (see below), *Refraction*, *Precession*, etc.

b. Orientation, use of incorrect *scale-value*, etc.

c. Errors of observation, both in the measured coördinates and in the meridian places.

Let us first consider the causes of difference under *a*; we shall then determine the orientation, true scale-value etc., by comparing the corrected coördinates with the corresponding values of $\Delta\alpha$

and $\Delta\delta$, eliminating the errors of observation as far as possible by means of a least-square solution.

I. TRANSFORMATION CORRECTIONS.

An astronomical photograph may be regarded as a central projection of a portion of the celestial sphere upon a tangent plane. The point on the plate which corresponds to the point of tangency is the foot of the perpendicular let fall from the optical centre of the object glass upon the plane of the plate. The rigorous relations between the rectilinear coördinates referred to this point as origin, and the right ascension and declination of a star, were given in simple form by Professor Turner in Vol. XVI, of "Observatory," page 374. Previous to this, however, Ball and Rambaut gave these relations in the form of series in their paper "On the Relative Positions of 223 stars in χ Persei," Transactions of the Royal Irish Academy, Vol. XXX, page 247. In our notation these formulas would be

$$\begin{aligned}\Delta\alpha - X\sec\delta_0 &= (X\sec\delta_0)\,Y\tan\delta_0 - \tfrac{1}{3}(X\sec\delta_0)^3 + (X\sec\delta_0)\,Y\tan^2\delta_0\\ \Delta\delta - Y &= -\tfrac{1}{4}(X\sec\delta_0)^2\sin 2\delta_0 - \tfrac{1}{3}Y^3 - \tfrac{1}{2}(X\sec\delta_0)^2\,Y\end{aligned}$$

The elegance of these formulas lies in the fact that the coefficients of the powers and products of X and Y, are functions of δ_0 only, and are therefore constant for a plate, or indeed for an entire zone. For most plates these series are sufficiently accurate, but when the declination or the measured coördinates are large they fail; in such cases we do not need to resort to the rigorous formulas but we have merely to extend the series to higher terms, as was done by Professor Jacoby in a review of a paper by Professor Donner, in the Vierteljahrschrift for 1895, page 114. In the same place, formulas are also given in which $\Delta\alpha$ and $\Delta\delta$ appear in the second members, instead of X and Y as above. Omitting terms of higher degree than the third, which is permissible for the Præsepe plates, these formulas may be written

$$\begin{aligned}\Delta\alpha - X\sec\delta_0 &= \Delta\alpha\cdot\Delta\delta\cdot\tan\delta_0 - \tfrac{1}{3}\Delta\alpha^3\left(1 - \tfrac{3}{2}\sin^2\delta_0\right)\\ \Delta\delta - Y &= -\tfrac{1}{4}\Delta\alpha^2\cdot\sin 2\delta_0 - \tfrac{1}{2}\Delta\alpha^2\cdot\Delta\delta\cdot\cos 2\delta_0 - \tfrac{1}{3}\Delta\delta^3\end{aligned}$$

The use of these formulas presupposes a knowledge of the approximate values of $\Delta\alpha$ and $\Delta\delta$ for each star. They possess two points of advantage over the inverse forms: first, there is one term less in the expression for $\Delta\alpha - X\sec\delta_0$; and second, they give slightly more accurate values for the corrections as they do not involve errors of orientation, scale-value, etc., such as would be incurred through the use of the measured X and Y in the second members. I have therefore used the latter expressions for computing the transformation corrections given in Table VI, employing the heliometer values of $\Delta\alpha$ and $\Delta\delta$ given by Professor Schur. It will be remembered that Rutherfurd was careful to make the central star 15 coincide with the foot of the perpendicular let fall from the optical centre of the object glass upon the plane of the plate. As our measured coördinates are referred to this star as origin, Table VI applies equally to all the plates.

TABLE VI.—TRANSFORMATION CORRECTIONS.

Star.	$\Delta\alpha - X \sec \delta_0$	$\Delta\delta - Y$	Star.	$\Delta\alpha - X \sec \delta_0$	$\Delta\delta - Y$
	″	″		″	″
1	—2.83	—3.01	24	—0.85	—0.22
2	+0.66	—2.80	25	—0.34	—0.26
3	+3.15	—2.58	26	—1.60	—0.23
4	+5.75	—2.23	27	—0 41	—0.28
5	—3.33	—1.22	28	+0.23	—0 29
6	—1.31	—0.77	29	+1.68	—0.36
7	+1.49	—0.52	31	—1.01	—0.35
7A	+0 21	—0.27	32	—2.92	—0.39
8	—0.84	—0.29	33	—3.08	—0.53
10	+0.36	—0.23	34	—0 34	—0.65
11	+0.60	—0.19	35	+3 24	—0 89
14	—0.02	—0.01	36	+1.13	—0.98
15	0.00	0.00	37	—1 41	—0.97
16	—0.16	+0.05	38	+0.45	—1.38
17	—0.20	—0.01	39	+1.28	—1.47
18	—0.31	—0.03	40	—4.84	—1 59
19	+0.54	—0.06	41	—1 24	—2 24
20	—0.36	—0.04	42	—1.35	—2.54
22	+0.51	—0.10	43	+1.19	—2.89
23	+0.53	—0.15	44	+4 79	—3.05
23A	+0.67	—0.18	45	—5.12	—3.66

II. CORRECTIONS FOR REFRACTION.

Formulas for clearing rectangular coördinates of the effects of refraction were first published by Dr. Rambaut in the "Astronomische Nachrichten," No. 3125. Professor Turner has shown how these may be much simplified by employing the coördinates of the zenith as projected upon the plate.* His formulas, however, will not serve in the transformation of rectangular coördinates into right ascensions and declinations unless we apply an extra correction for orientation. (See note at the end of this paper.) The formulas that I have preferred to use are those given by Professor Jacoby;* while these are not quite so simple as those of Professor Turner, they take into account the orientation correction mentioned. Let

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* Monthly Notices, R.A.S., November, 1893.

φ = the latitude, $+40^\circ 44'$ in this case.

$\theta - \alpha_0$ = the hour angle of the centre of the plate, from Table I.

δ_0 = the declination of the centre, $+20^\circ 13'$

β = the constant of refraction, computed in the usual way and then multiplied by $\frac{66}{65}$ to allow for the increased refrangibility of photographic rays.†

Now let us compute:

$$\begin{aligned}
\tan N &= \cos(\theta - \alpha_0) \cot \varphi \\
G &= \cot(\delta_0 + N) \\
H &= \tan(\theta - \alpha_0) \sin N \operatorname{cosec}(\delta_0 + N) \\
M_x &= \beta(1 + H^2) \\
N_x &= \beta(G - \tan \delta_0) H \sec \delta_0 \\
M_y &= \beta(G + \tan \delta_0) H \cos \delta_0 \\
N_y &= \beta(1 + G^2)
\end{aligned}$$

Then the corrections for refraction take the form:

$$\text{Correction for } X \sec \delta_0 = M_x \cdot X \sec \delta_0 + N_x \cdot Y$$
$$\text{“} \qquad \text{“} \qquad Y = M_y \cdot X \sec \delta_0 + N_y \cdot Y$$

The coefficients of $X \sec \delta_0$ and of Y in the second members are constant for an entire plate. We may then construct Table VII, in which the number of the plate is the argument.

TABLE VII.—REFRACTION COEFFICIENTS.

Plate.	M_x	N_x	M_y	N_y
I.	0.000356	0.000017	0.000114	0.000349
II.	0.000423	0.000042	0.000174	0.000375
III.	0.000404	0.000031	0.000153	0.000373
IV.	0.000523	0.000086	0.000255	0.000424
V.	0.000357	0.000015	0.000110	0.000354
VII.	0.000423	0.000042	0.000174	0.000375
VIII.	0.000491	0.000074	0.000233	0.000404
IX.	0.000377	0.000023	0.000131	0.000360

All the coefficients are positive.

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* Astronomical Journal, No. 387.

† Bulletin du Comité Permanent, I, 464; and Scheiner and Rambaut, Astron. Nach. 3255.

III. PRECESSION AND NUTATION.

These merely change the position of the axes to which the group is referred; it follows therefore that their *differential* effect upon X and Y is simply to rotate the coördinate axes through a small angle. When we determine the constants of a plate by comparing the measures of some of the stars with their true positions, it is evident that we need apply no corrections for precession and nutation to the measures of the comparison stars. Thus if we employ the places of the latter as referred to the equinox of 1875.0. then the value for the orientation which we shall get will include the necessary correction for precession and nutation. On the other hand, if we correct the places of the comparison stars for precession and nutation, then it would not only be necessary to apply the resulting orientation correction to the *other* stars, but we should also have to apply to them additional corrections for precession and nutation.

IV. ABERRATION.

It was shown by Bessel* that aberration changes the position angles around a point equally, and changes the distances by a constant factor, no matter in what direction the distance is measured. Consequently, as in the case of precession and nutation, we need apply no correction for aberration to the measures of the comparison stars, since the resulting orientation and scale-value corrections will be appropriately modified to include its whole effect.

Thus we see that the coördinates of our five comparison stars need be corrected only for transformation and refraction. We must bear in mind, however, that the orientation and the scale-value which we shall then obtain are not the true values of these constants: the former must be corrected for precession, nutation and aberration, and the latter simply for aberration.

We are now ready to find the constants of the plates. Let

$p =$ the correction to the scale-value, so that the true scale-value is $52''.87\ (1 + p)$.

$r =$ the orientation correction, or the small angle through which the axes are to be rotated in the direction of decreasing position angles.

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* "Astronomische Untersuchungen," Vol. I, page 207.

k = the number of seconds of arc of a great circle through which the axes are to be translated in the direction of decreasing right ascensions.

c = the number of seconds of arc of a great circle through which the axes are to be translated in the direction of decreasing declinations.

The corrections to the rectangular coördinates arising from p are then:

$$\begin{array}{ll} \text{For } X, & +p \cdot X \\ \text{"} \quad Y, & +p \cdot Y \end{array}$$

On account of the orientation corrections, remembering that r is small, we have the corrections:

$$\begin{array}{ll} \text{For } X, & +r \cdot Y \\ \text{"} \quad Y, & -r \cdot X \end{array}$$

Finally, k and c give the corrections:

$$\begin{array}{ll} \text{For } X, & +k \\ \text{"} \quad Y, & +c \end{array}$$

Combining all these corrections, we have:

$$\begin{array}{ll} \text{For } X, & +p \cdot X + r \cdot Y + k \\ \text{"} \quad Y, & +p \cdot Y - r \cdot X + c \end{array}$$

Let us now compute n_x and n_y for each comparison star, from the following equations:

$n_x \sec \delta_0 = X \sec \delta_0$ *plus* corrections for transformation and refraction, *minus* $\Delta\alpha$.

$n_y \quad = Y$ *plus* corrections for transformation and refraction, *minus* $\Delta\delta$.

Then for each comparison star we have two equations of the following form from which to determine p, r, k and c:

$$pX + rY + k + n_x = 0$$

$$pY - rX + c + n_y = 0$$

Owing to the way in which the coefficients of the unknowns are repeated in these equations we do not need to make the least square solution in the usual manner, but as Professor Jacoby has pointed out,* we may find the unknowns very simply. Thus, let ν = the number of comparison stars, and let us denote by square brackets the sum of ν quantities.

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* Monthly Notices of the Royal Astronomical Society, May, 1896.

Put

$$A = [XX] + [YY] - \frac{1}{\nu}([X]^2 + [Y]^2)$$

$$C = [X \cdot n_x] + [Y \cdot n_y] - \frac{1}{\nu}([X][n_x] + [Y][n_y])$$

$$E = [Y \cdot n_x] - [X \cdot n_y] - \frac{1}{\nu}([Y][n_x] - [X][n_y])$$

Then we have:

$$p = -\frac{C}{A}, \text{ with the weight } A.$$

$$r = -\frac{E}{A}, \quad \text{“} \quad \text{“} \quad \text{“} \quad A.$$

$$k \quad -\frac{1}{\nu}([X]p + [Y]r + [n_x]), \text{ with the weight, } \nu - \frac{[X]^2 + [Y]^2}{[XX] + [YY]}$$

$$c = -\frac{1}{\nu}([Y]p - [X]r + [n_y]), \quad \text{“} \quad \text{“} \quad \text{“} \quad \nu - \frac{[X]^2 + [Y]^2}{[XX] + [YY]}$$

The following will be found a convenient check on the computations: the sum of the residuals for the right ascension equations is equal to zero, and similarly for the declination equations.*

The above method of solution is rendered still simpler in the present case, as we are going to use the same comparison stars for all the plates. Hence all the terms in the expressions for A, C and E are constant except those which involve n_x or n_y. Thus, selecting the coördinates of the comparison stars from any plate in Table V, and multiplying them by 52.87 we have, with sufficient accuracy:

	X	Y
4	—1620″	—1850″
5	—1140	+1530
15	0	0
40	+1370	—1850
44	+1820	+1390

Consequently, for all the plates,

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* This is indeed a general check for any set of observation equations in which one of the unknowns enters with a constant coefficient; if this unknown is missing from some of the equations, then the sum of the residuals for those equations in which it does appear is equal to zero. The theorem may be easily modified to include the case of unequal weights.

$$A = 20{,}080{,}000$$

$$C = [X \cdot n_x] + [Y \cdot n_y] - 86\,[n_x] + 156\,[n_y]$$

$$E = [Y \cdot n_x] - [X \cdot n_y] + 156\,[n_x] - 86\,[n_y]$$

$$p = -\frac{C}{20{,}080{,}000}\,;\quad \text{weight, } 20{,}080{,}000$$

$$r = -\frac{E}{20{,}080{,}000}\,;\quad \text{`` } \quad 20{,}080{,}000$$

$$k = -86p + 156r - 0.20\,[n_x]\,;\quad \text{weight, } 4.96$$

$$c = +156p + 86r - 0.20\,[n_y]\,;\quad \text{`` } \quad 4.96$$

It now remains to show how the right ascensions and declinations of all the stars may be computed. The constants of the plate give rise to the corrections:

$$\begin{array}{lllll} \text{For } X \sec \delta_0, & +p \cdot X \sec \delta_0 & + r \sec \delta_0 \cdot Y & + k \sec \delta_0 \\ \text{`` } \; Y \quad , & +p \cdot Y & - r \;\; X & + c \end{array}$$

The corrections for refraction are:

$$\begin{array}{lll} \text{For } X \sec \delta_0, & + M_x \cdot X \sec \delta_0 & + N_x \cdot Y \\ \text{`` } \; Y \quad , & + M_y \cdot X \sec \delta_0 & + N_y \;\; Y \end{array}$$

We have still to add corrections for transformation, which vary from star to star, but are the same for different plates. Now let us define α_1 and δ_1 as the *projected* right ascension and declination respectively of a star, the true right ascension and declination being given thus:

$\alpha = \alpha_1$ *plus* the correction for transformation.

$\delta = \delta_1$ *plus* the correction for transformation.

Then collecting the corrections given above:

$$\alpha_1 = (1 + p + M_x)\, X \sec \delta_0 + (N_x + r \sec \delta_0)\, Y + (\alpha_0 + k \sec \delta_0)$$
$$\delta_1 = (1 + p + N_y)\, Y \quad + (M_y - r \cos \delta_0)\, X \sec \delta_0 + (\delta_0 + c)$$

Hence, to get the projected right ascension and declination of any star, the constants of the plate having been determined, we need only compute the six coefficients in the parentheses and perform the simple operations indicated. These coefficients, it is needless to remark, are constant for an entire plate.

As an example of the above methods I have set down the details of the computations for the constants of Plate VIII.

Right Ascensions.

Star	4	5	15	40	44
x : (Table V),	−30.6580	−21.5809	0	+25.9804	+34.4505
$X \sec \delta_0 = 52.87 \sec \delta_0 \cdot x$,	−1727″.31	−1215″.89	0″	+1463″.77	+1940″.98
$M_x \cdot X \sec \delta_0$: (Tab. VII),	− 0.85	− .60	0	+ 0.72	+ 0.95
$N_x \cdot Y$: (See below),	− 0.14	+ .12	0	− 0.14	+ 0.11
$\Delta\alpha - X \sec \delta_0$: (Tab. VI),	+ 5.75	− 3.33	0	− 4.84	+ 4.79
$-\Delta\alpha$: (Page 237),	+1723.40	+1219.75	0	−1459.48	−1948.19
$n_x \sec \delta_0$:	+ 0.85	+ 0.05	0	+ 0.03	− 1.36
n_x :	+ 0.80	+ 0.05	0	+ 0.03	− 1.28

Declinations.

Star.	4	5	15	40	44
y : (Table V),	−35.0520	+28.9675	0	−34.9240	+26.3259
$Y = 52.87\, y$:	−1853″.20	+1531″.51	0″	−1846″.43	+1391″.85
$N_y \cdot Y$: (Table VII),	− 0.75	+ 0.62	0	− 0.75	+ 0.56
$N_x \cdot X \sec \delta_0$: (See above),	− 0.40	− 0.28	0	+ 0.34	+ 0.46
$\Delta\delta - Y$: (Table VI),	− 2.23	− 1.22	0	− 1.59	− 3.05
$-\Delta\delta$: (Page 237),	+1856.81	−1531.17	0	+1849.40	−1390.15
n_y :	+ 0.23	− 0.54	0	+ 0.97	− 0.33

$$[X \cdot n_x] = -3650 \quad [Y \cdot n_x] = -3240 \quad [n_x] = -0''.40$$
$$[X \cdot n_y] = +980 \quad [Y \cdot n_y] = -3510 \quad [n_y] = +0''.33$$

$$p = +0.000352 \qquad \pm 0.000030$$
$$r = +0.000211 \qquad \pm 0.000030$$
$$k = +0''.08 \qquad \pm 0''.061$$
$$c = +0''.01 \qquad \pm 0''.061$$

Having found the constants, we may now proceed to get the right ascension and declination of each star on the plate. For this purpose we compute the coefficients:

For Right Ascensions	For Declinations.
$52.87\,(1 + p + M_x) \sec \delta_0 = 56.3887$	$52.87\,(1 + p + N_y) = 52.9100$
$N_x + r \sec \delta_0 = +0.000299$	$M_y - r \cos \delta_0 = +0.000035$
$a_0 + k \sec \delta_0 = 128°07'54''.84$	$\delta_0 + c = 20°13'01''.39$

A slight change has been made in the two coefficients in the first line, our formulas requiring $(1+p+M_x)$ and $(1+p+N_y)$. This change, however, merely amounts to combining two multiplications into one; thus, instead of first computing $X \sec \delta_0$ and then multiplying this by $(1+p+M_x)$, we may apply the factor $52.87(1+p+M_x) \sec \delta_0$ to x directly. The formulas require that we know $X \sec \delta_0$ in computing the correction to the declination, but for this purpose we may use $52.87(1 + p + M_x) \sec \delta_0 \cdot x$, the quantity which we have just computed and which is practically equal to $X \sec \delta_0$ for this purpose. Similarly in the declination we may compute at once $52.87(1 + p + N_y)$.

Employing these coefficients for Star 7 we have:

Right Ascension:		Declination:	
x : (Tab. V),	$-\ 14.6960$	y : (Tab. V),	$-\ 19.0252$
$52.87(1+p+M_x) \sec \delta_0 \cdot x$:	$-\ 828.''69$	$52.87(1+y+N_y) \cdot y$:	$-\ 1006''.62$
	$= -13'48.69$		$= -16'46''.62$
$(N_x + r \sec \delta_0) \cdot Y$:	$-\quad 0.30$	$(M_y - r \sec \delta_0) \cdot X \sec \delta_0$:	$-\quad 0.03$
$a_0 + k \sec \delta_0$:	$128^\circ 07\ 54\ .84$	$\delta_0 + c$:	$+20^\circ 13\ 01\ .39$
$a_1 \quad =$	$127^\circ 54' 05''.85$	$\delta_1 =$	$+19^\circ 56' 14''.74$

These give the projected position; the true right ascension and declination are found by adding the transformation corrections from Table VI, giving:

$$a = 127^\circ 54' 7''.34\,,\quad \delta = +19^\circ 56' 14''.22,$$

which are corrected for refraction, precession, nutation and aberration, and are referred to the mean equinox of 1875.0.

V.

Results.

Least-square solutions entirely similar to that given in detail in the last section lead to the following values of *p*, *r*, etc., for the various plates:

CONSTANTS OF THE PLATES.

Plate.	*p*	*r*	Probable Error of *p* or *r*.	*k*	*c*	Probable Error of *k* or *c*.
I.	+0.000100	+0.001054	±0.000037	—0″.06	0″.00	±0″.075
II.	+ 125	+ 844	± 45	—0.18	—0.15	±0.092
III.	+ 125	+ 409	± 32	—0.22	—0.06	±0.066
IV.	+ 209	+ 1435	± 41	0.00	—0.03	±0.082
V.	+ 261	+ 172	± 22	—0.01	+0.01	±0.044
VII.	+ 342	— 35	± 24	+0.02	—0.04	±0.049
VIII.	+ 352	+ 211	± 30	+0.08	+0.01	±0.061
IX.	+ 365	— 326	± 24	—0.06	—0.01	±0.048

The average probable error of *p* or *r* is

±0.000032

which corresponds to an uncertainty of about 0″.06 in the coördinates of the outlying stars. The great diversity in the values of *r* is due in small part to corrections for precession, nutation and aberration, but chiefly to the accidental position in which the plate was inserted in the measuring machine.

The following are the residuals for the five comparison stars, used in computing the values of *p*, *r*, *k* and *c* given above.

Residuals from the Right Ascension Equations:

Plate.	Star 4.	Star 5.	Star 15.	Star 40.	Star 44.
I	0″.00	+0″.03	—0″.01	+0″.07	—0″.09
II	— .24	+ .31	— .18	+ .42	— .31
III	— .14	+ .20	— .23	+ .28	— .11
IV	— .19	+ .13	.00	+ .39	— .33
V	— .01	+ .13	— .06	+ .25	— .31
VII	— .07	+ .09	+ .02	+ .14	— .18
VIII	— .08	+ .05	+ .08	+ .21	— .26
IX	+ .10	— .09	— .06	+ .12	— .08
Means,	— .08	+ .11	— .06	+ .24	—.21

Residuals from the Declination Equations:

Plate.	Star 4.	Star 5.	Star 15.	Star 40.	Star 44.
	$''$	$''$	$''$	$''$	$''$
I	−0.13	+0.20	+0.01	+0.10	−0.18
II	− .03	+ .20	− .15	+ .11	− .13
III	− .07	+ .13	− .06	+ .16	− .16
IV	− .00	+ .23	− .04	+ .07	− .26
V	− .09	+ .34	.00	− .01	− .24
VII	− .10	+ .22	− .04	+ .08	− .16
VIII	− .08	+ .25	+ .01	+ .04	− .22
IX	− .02	+ .23	− .01	+ .03	− .23
Means,	− .06	+ .22	− .03	+ .07	− .20

Employing the constants in the manner described at length in the last section, we obtain the quantities α_1 and δ_1 which have been tabulated in the following pages. It will be remembered that α_1 and δ_1 are the projected right ascension and declination of a star respectively; the transformation correction being the same for all the plates, may just as well be applied to the means; and it is evident that this procedure does not affect in any way the comparison of the right ascensions or declinations of a star as derived from different plates. The columns headed "At Epoch of Plate" give the coördinates uncorrected for proper motion. The calculation of the latter is very simple in this case as the plates were taken at practically only two dates, 1870.3 and 1877.3; hence the annual proper motion is obtained by subtracting the mean of the places on plates of the earlier date from the mean for the later date, and dividing the difference by 7. The columns marked "P. M." give the correction for proper motion necessary to reduce the place of the star to the epoch 1875.0.

Probable errors are given for the right ascension and the declination of each star, and also for the proper motions; they were calculated thus:

Let m = the number of plates of date 1870.3 on which the star was measured.

n = the number of date 1877.3.

$[vv]$ = the sum of the squares of the residuals obtained by subtracting the mean from the separate observations reduced to the epoch 1875.0.

Then the probable error of a quantity having the weight unity

$$\pm 0.6745 \sqrt{\frac{[vv]}{m+n-2}}$$

The weight of a right ascension or a declination at the epoch 1875.0 is

$$\frac{49mn}{22.1\,m + 5.3\,n}$$

For a proper motion the weight is

$$\frac{49mn}{m+n}$$

Most of the stars appear on all eight plates; for such we have simply,

$$\text{Probable error of } \alpha_1 \text{ or of } \delta_1 = \pm 0.103 \sqrt{[vv]}$$

$$\text{“ \quad “ of proper motion} = \pm 0.028 \sqrt{[vv]}$$

Two of the stars were observed only on plates taken in 1877, and consequently it was not possible to reduce them to the epoch 1875.0 by using proper motions determined from the plates themselves, as has been done for all the other stars. The proper motions used for these two stars are those given by Professor Schur on page 298 of his memoir, and are as follows:

Star.	P. M. in Right Ascension.	P. M. in Declination.
41	—0″.042	+0″.012
42	—0 .066	+0 .036

These were used for an interval of only 2.3 years.

STAR I.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	127°35′31″.25	—0″.43	30″.82	20°26′52″.60	+0″.15	52″.75
II	30 .80	— .43	.37	.47	+ .15	.62
III	30 .94	— .43	.51	.52	+ .15	.67
IV	31 .16	— .43	.73	.64	+ .15	.79
V	30 .46	+ .21	.67	.84	— .07	.77
VII	30 .47	+ .21	.68	.79	— .07	.72
VIII	30 .45	+ .21	.66	.60	— .07	.53
IX	30 .22	+ .21	.43	.90	— .07	.83
	Mean,		127°35′30″.61	Mean,		20°26′52″.71
	Probable Error,		±.041	Probable Error,		±.026
	Proper Motion,		—0.091 ±0.011	Proper Motion,		+0.032 ±0.007

STAR 2.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	127°36′26″.17	—0″.31	25″.86	20°10′02″.04	+0″.15	2″.19
II	26 .21	— .31	.90	.10	+ .15	.25
III	26 .03	— .31	.72	.06	+ .14	.20
IV	26 .15	— .31	.84	.14	+ .14	.28
V	25 .74	+ .15	.89	.26	— .07	.19
VII	25 .65	+ .15	.80	.32	— .07	.25
VIII	25 .60	+ .15	.75	.24	— .07	.17
IX	25 .71	+ .15	.86	.40	— .07	.33
	Mean,		127°36′25″.83	Mean,		20°10′02″.23
	Probable Error,		±.018	Probable Error,		±.015
	Proper Motion,		—0.066 ±0.005	Proper Motion,		+0.031 ±0.004

STAR 3.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	127°37′28″.20	—0″.38	27″.82	19°57′10″.51	+0″.01	10″.52
III	27 .95	— .38	.57	.32	+ .01	.33
IV	27 .98	— .38	.60	.42	+ .01	.43
V	27 .53	+ .19	.72	.50	.00	.50
VII	27 .39	+ .19	.58	.39	.00	.39
VIII	27 .36	+ .19	.55	.34	.00	.34
IX	27 .62	+ .19	.81	.49	— .01	.48
	Mean,		127°37′27″.66	Mean,		19°57′10″.43
	Probable Error,		±.032	Probable Error,		±.021
	Proper Motion,		—0.081 ±0.009	Proper Motion,		+0.002 ±0.006

STAR 4.

Plate	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	127°39′06″.16	—0″.29	5″.87	19°42′06″.67	+0″.01	6″.68
II	5 .92	— .29	.63	.72	+ .01	.73
III	6 .04	— .29	.75	.68	+ .01	.69
IV	5 .97	— .29	.68	.74	+ .01	.75
V	5 .60	+ .14	.74	.66	.00	.66
VII	5 .54	+ .14	.68	.70	.00	.70
VIII	5 .52	+ .14	.66	.73	.00	.73
IX	5 .71	+ .14	.85	.77	— .01	.76
	Mean,		127°39′05″.73	Mean,		19°42′06″.71
	Probable Error,		±.024	Probable Error,		±.010
	Proper Motion,		—0.061 ±0.007	Proper Motion,		+0.002 ±0.003

STAR 5.

Plate.	Right Ascension: At Epoch of Plate	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	127°47′38″.48	—0″.14	8″.34	20°38′33″.84	+0″.17	34″.01
II	.68	— .14	.54	33 .71	+ .17	33 .88
III	.57	— .14	.43	33 .64	+ .17	33 .81
IV	.48	— .14	.34	33 .74	+ .17	33 .91
V	.35	+ .07	.42	33 .97	— .08	33 .89
VII	.41	+ .07	.48	33 .99	— .09	33 .90
VIII	.38	+ .07	.45	34 .01	— .09	33 .92
IX	.22	+ .07	.29	34 .01	— .09	33 .92
	Mean,		127°47′38″.41	Mean,		20°38′33″.91
	Probable Error,		±.022	Probable Error,		±.015
	Proper Motion,		—0.030 ±0.006	Proper Motion,		+0.037 ±0.004

STAR 6.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	127°51′33″.81	—0″.32	33″.49	20°25′33″.46	+0″.21	33″.67
II	.66	— .32	.34	.16	+ .21	.37
III	.77	— .32	.45	.30	+ .21	.51
IV	.97	— .32	.65	.52	+ .21	.73
V	.47	+ .16	.63	.66	— .10	.56
VII	.34	+ .16	.50	.61	— .10	.51
VIII	.26	+ .16	.42	.64	— .10	.54
IX	.20	+ .16	.36	.76	— .10	.66
	Mean,		127°51′33″.48	Mean,		20°25′33″.57
	Probable Error,		±.031	Probable Error,		±.031
	Proper Motion,		—0.069 ±0.009	Proper Motion,		+0.044 ±0.009

STAR 7.

Plate.	Right Ascension .			Declination :		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	127°54′06″.35	—0″.33	6″.02	19°56′14″.87	—0″.03	14″.84
II	6 .36	— .33	6 .03	.70	— .03	.67
III	6 .16	— .33	5 .83	.63	— .03	.60
IV	6 .46	— .33	6 .13	.88	— .03	.85
V	5 .91	+ .16	6 .07	.76	+ .01	.77
VII	5 .81	+ .16	5 .97	.74	+ .01	.75
VIII	5 .85	+ .16	6 .01	.74	+ .01	.75
IX	5 .77	+ .17	5 .94	.66	+ .01	.67
	Mean,		127°54′06″.00	Mean,		19°56′14″.74
	Probable Error,		±.025	Probable Error,		±.024
	Proper Motion,		—0.071 ±0.007	Proper Motion,		—0.006 ±0.007

STAR 7A.

Plate.	Right Ascension :			Declination :		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M	At Epoch 1875.0.
II	127°57′58″.00	—0″.47	57″.53	20°09′42″.62	—0″.09	42″.53
IV	58 .26	— .47	.79	.55	— .09	.46
VII	57 .61	+ .23	.84	.57	+ .04	.61
VIII	57 .25	+ .23	.48	.34	+ .04	.38
	Mean,		127°57′57″.66	Mean.		20°09′42″.50
	Proper Motion,		—0.100	Proper Motion,		—0.019

STAR 8.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	127°57′59″.38	—0″.34	9″.04	20°26′12″.54	+0″.12	12″.66
II	59 .38	— .34	.04	.51	+ .12	.63
III	59 .64	— .34	.30	.63	+ .12	.75
IV	59 .42	— .34	.08	.69	+ .12	.81
V	59 .08	+ .17	.25	.79	— .06	.73
VII	58 .90	+ .17	.07	.69	— .06	.63
VIII	58 .86	+ .17	.03	.70	— .06	.64
IX	58 .95	+ .17	.12	.88	— .06	.82
	Mean,		127°57′59″.12	Mean,		20°26′12″.71
	Probable Error,		±.028	Probable Error,		±.022
	Proper Motion,		—0.072 ±0.008	Proper Motion,		+0.025 ±0.006

STAR 10.

Plate.	Right Ascension:			Declination		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate	P. M.	At Epoch 1875.0.
I	127°58′48″.65	—0″.19	48″.46	20°06′50″.40	+0″.14	50″.54
II	.76	— .19	.57	.33	+ .14	.47
III	.83	— .19	.64	.27	+ .14	.41
IV	.77	— .19	.58	.34	+ .14	.48
V	.47	+ .09	.56	.52	— .07	.45
VII	.34	+ .09	.43	.58	— .07	.51
VIII	.42	+ .09	.51	.48	— .07	.41
IX	.67	+ .09	.76	.56	— .07	.49
	Mean,		127°58′48″.56	Mean,		20°06′50″.47
	Probable Error,		±.028	Probable Error,		±.012
	Proper Motion,		—0.040 ±0.008	Proper Motion,		+0.029 ±0.003

STAR 11.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	127°59′36″.89	−0″.35	36″.54	20°01′46″.90	+0″.10	47″.00
II	36 .86	− .35	.51	46 .86	+ .10	46 .96
III	36 .96	− .35	.61	46 .80	+ .10	46 .90
IV	37 .08	− .35	.73	46 .76	+ .10	46 .86
V	36 .63	+ .17	.80	46 .95	− .05	46 .90
VII	36 .36	+ .17	.53	46 .96	− .05	46 .91
VIII	36 .40	+ .17	.57	46 .83	− .05	46 .78
IX	36 .29	+ .17	.46	47 .16	− .05	47 .11
	Mean,		127°59′36″.59	Mean,		20°01′46″.93
	Probable Error,		±.032	Probable Error,		±.027
	Proper Motion,		−0.075 ±0.009	Proper Motion,		+0.021 ±0.008

STAR 14.

Plate.	Right Ascension			Declination		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M	At Epoch 1875.0.
I	128°07′45″.06	−0″.20	44″.86	20°31′29″.10	+0″.13	29″.23
II	44 .81	− .20	.61	29 .00	+ .13	.13
III	44 .98	− .20	.78	28 .88	+ .13	.01
IV	45 .15	− .20	.95	29 .01	+ .13	.14
V	44 .82	+ .10	.92	29 .07	− .06	.01
VII	44 .60	+ .10	.70	29 .19	− .06	.13
VIII	44 .75	+ .10	.85	29 .23	− .06	.17
IX	44 .64	+ .10	.74	29 .26	− .06	.20
	Mean,		128°07′44″.80	Mean,		20°31′29″.13
	Probable Error,		±.031	Probable Error,		±.022
	Proper Motion,		−0.042 ±0.009	Proper Motion,		+0.027 ±0.006

STAR 15.

Plate.	Right Ascension.			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°07′55″.19	—0″.25	54″.94	20°13′01″.26	+0″.12	1″.38
II	55 .07	— .25	54 .82	.11	+ .12	.23
III	55 .02	— .25	54 .77	.20	+ .12	.32
IV	55 .26	— .25	55 .01	.23	+ .12	.35
V	54 .74	+ .12	54 .86	.39	— .06	.33
VII	54 .77	+ .12	54 .89	.34	— .06	.28
VIII	54 .84	+ .12	54 .96	.39	— .06	.33
IX	54 .69	+ .13	54 .82	.37	— .06	.31
	Mean,		128°07′54″.88	Mean,		20°13′01″.32
	Probable Error,		±.022	Probable Error,		±.012
Proper Motion,			—0.054 ±0.006	Proper Motion,		+0.025 ±0.003

STAR 16.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°08′44″.80	—0″.34	44″.46	19°42′50″.00	+0″.03	50″.03
II	.79	— .34	.45	50 .08	+ .03	50 .11
III	.73	— .34	.39	49 .91	+ .03	49 .94
IV	.98	— .34	.64	49 .85	+ .03	49 .88
V	.38	+ .17	.55	49 .97	— .01	49 .96
VII	.41	+ .17	.58	50 .00	— .01	49 .99
VIII	.32	+ .17	.49	49 .95	— .01	49 .94
IX	.15	+ .17	.32	50 .08	— .01	50 .07
	Mean,		128°08′44″.48	Mean,		19°42′49″.99
	Probable Error,		±.028	Probable Error,		±.021
Proper Motion,			—0.073 ±0.008	Proper Motion,		+0.006 ±0.006

Star 17.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°10′05″.46	—0″.27	5″.19	19°48′46″.81	+0″.09	46″.90
II	5 .17	— .27	4 .90	.83	+ .09	.92
III	5 .36	— .27	5 .09	.81	+ .08	.89
IV	5 .57	— .27	5 .30	.75	+ .08	.83
V	5 .03	+ .13	5 .16	.88	— .04	.84
VII	5 .06	+ .13	5 .19	.90	— .04	.86
VIII	5 .01	+ .13	5 .14	.93	— .04	.89
IX	4 .83	+ .14	4 .97	.99	— .04	.95
	Mean,		128°10′05″.12	Mean,		19°48′46″.89
	Probable Error,		±.035	Probable Error,		±.011
	Proper Motion,		—0.058 ±0.010	Proper Motion,		+0.018 ±0.003

Star 18.

Plate.	Right Ascension.			Declination.		
	At Epoch of Plate	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°11′32″.44	—0″.22	32″.22	19°59′31″.64	+0″.10	31″.74
II	32 .26	— .22	32 .04	.53	+ .10	.63
III	32 .20	— .21	31 .99	.44	+ .10	.54
IV	32 .28	— .21	32 .07	.48	+ .10	.58
V	32 .05	+ .11	32 .16	.74	— .05	.69
VII	31 .95	+ .11	32 .06	.60	— .05	.55
VIII	32 .04	+ .11	32 .15	.64	— .05	.59
IX	31 .86	+ .11	31 .97	.69	— .05	.64
	Mean,		128°11′32″.08	Mean,		19°59′31″.62
	Probable Error,		±.024	Probable Error,		±.019
	Proper Motion,		—0.046 ±0.007	Proper Motion,		+0.021 ±0.005

STAR 19.

Plate.	Right Ascension.			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0	At Epoch of Plate.	P. M.	At Epoch 1875.0.
II	128°11′36″.06	—0″.25	35″.81	20°35′50″.68	+0″.09	50″.77
IV	36 .37	— .25	36 .12	.64	+ .09	.73
V	35 .95	+ .12	36 .07	.69	— .04	.65
VII	35 .86	+ .12	35 .98	.87	— .04	.83
VIII	35 .72	+ .12	35 .84	.82	— .04	.78
Mean,			128°11′35″.96	Mean,		20°35′50″.75
Proper Motion,			—0.053	Proper Motion,		+0.019

STAR 20.

Plate.	Right Ascension			Declination		
	At Epoch of Plate.	P. M.	At Epoch 1875.0	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°11′51″.88	—0″.20	51″.68	19°58′50″.40	+0″.08	50″.48
II	.77	— .20	.57	.42	+ .08	.50
III	.75	— .20	.55	.39	+ .08	.47
IV	.77	— .20	.57	.40	+ .08	.48
V	.49	+ .10	.59	.50	— .04	.46
VII	.42	+ .10	.52	.37	— .04	.33
VIII	.51	+ .10	.61	.50	— .04	.46
IX	.58	+ .10	.68	.68	— .04	.64
Mean,			128°11′51″.60	Mean,		19°58′50″.48
Probable Error,			±.016	Probable Error,		±.023
Proper Motion,			—0.042 ±0.004	Proper Motion,		+0.016 ±0.006

STAR 22.

Plate.	Right Ascension.			Declination:		
	At Epoch of Plate.	P. M	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°12′43″.03	—0″.32	42″.71	20°26′50″.07	+0″.13	50″.20
II	42 .70	— .32	.38	.12	+ .13	.25
III	42 .98	— .32	.66	.04	+ .13	.17
IV	43 .08	— .32	.76	.04	+ .13	.17
V	42 .36	+ .16	.52	.20	— .06	.14
VII	42 .33	+ .16	.49	.20	— .06	.14
VIII	42 .57	+ .16	.73	.35	— .06	.29
IX	42 .63	+ .16	.79	.28	— .06	.22
	Mean,		128°12′42″.63	Mean,		20°26′50″.20
	Probable Error,		±.040	Probable Error,		±.015
	Proper Motion,		—0.068 ±0.011	Proper Motion,		+0.027 ±0.004

STAR 23.

Plate.	Right Ascension:			Declination		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Place.	P. M.	At Epoch 1875.0.
I	128°14′60″.24	—0″.23	60″.01	20°34′39″.08	+0″.19	39″.27
II	59 .92	— .23	59 .69	38 .93	+ .19	.12
III	59 .81	— .23	59 .58	38 .91	+ .19	.10
IV	60 .20	— .23	59 .97	38 .94	+ .19	.13
V	59 .85	+ .11	59 .96	39 .21	— .09	.12
VII	59 .54	+ .11	59 .65	39 .18	— .09	.09
VIII	59 .71	+ .11	59 .82	39 .18	— .09	.09
IX	59 .69	+ .11	59 .80	39 .41	— .09	.32
	Mean,		128°14′59″.81	Mean,		20°34′39″.16
	Probable Error,		±.044	Probable Error,		±.025
	Proper Motion,		—0.049 ±0.012	Proper Motion,		+0.040 ±0.007

STAR 23A.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°15′57″.80	—0″.32	57″.48	20°26′03″.10	+0″.09	3″.19
II	.74	— .32	.42	2 .80	+ .09	2 .89
III	.70	— .32	.38	3 .00	+ .09	3 .09
IV	.96	— .32	.64	2 .96	+ .09	3 .05
V	.42	+ .16	.58	3 .10	— .05	3 .05
VII	.28	+ .16	.44	3 .09	— .05	3 .04
VIII	.27	+ .16	.43	3 .12	— .05	3 .07
IX	.29	+ .16	.45	3 .12	— .05	3 .07
	Mean,		128°15′57″.48	Mean,		20°26′03″.06
	Probable Error,		±.024	Probable Error,		±.022
	Proper Motion,		—0.069 ±0.007	Proper Motion,		+0.020 ±0.006

STAR 24.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°16′58″.57	—0″.21	58″.36	19°58′19″.27	+0″.07	19″.34
II	58 .24	— .21	58 .03	.16	+ .07	.23
III	58 .57	— .21	58 .36	.22	+ .07	.29
IV	58 .67	— .21	58 .46	.11	+ .07	.18
V	58 .19	+ .10	58 .29	.29	— .03	.26
VII	57 .89	+ .10	57 .99	.24	— .03	.21
VIII	58 .32	+ .10	58 .42	.27	— .03	.24
IX	58 .38	+ .10	58 .48	.38	— .04	.34
	Mean,		128°16′58″.30	Mean,		19°58′19″.26
	Probable Error,		±.051	Probable Error,		±.016
	Proper Motion,		—0.045 ±0.014	Proper Motion,		+0.015 ±0.004

STAR 25.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°17′32″.03	—0″.25	31″.78	20°07′36″.79	+0″.07	36″.86
II	31 .70	— .25	.45	.67	+ .07	.74
III	31 .57	— .25	.32	.60	+ .07	.67
IV	31 .95	— .25	.70	.69	+ .07	.76
V	31 .39	+ .12	.51	.73	— .03	.70
VII	31 .38	+ .12	.50	.82	— .03	.79
VIII	31 .38	+ .12	.50	.75	— .03	.72
IX	31 .59	+ .13	.72	.86	— .04	.82
	Mean,		128°17′31″.56	Mean,		20°07′36″.76
	Probable Error,		±.043	Probable Error,		±.016
	Proper Motion,		—0.054 ±0.012	Proper Motion,		+0.015 ±0.004

STAR 26.

Plate.	Right Ascension			Declination		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0
I	128°17′37″.23	—0″.30	36″.93	19°47′20″.91	+0″.03	20″.94
II	36 .92	— .30	.62	21 .01	+ .03	21 .04
III	36 .98	— .29	.69	20 .83	+ .03	20 .86
IV	37 .12	— .29	.83	20 .76	+ .03	20 .79
V	36 .49	+ .14	.63	20 .82	— .02	20 .80
VII	36 .64	+ .15	.79	20 .90	— .02	20 .88
VIII	36 .79	+ .15	.94	20 .89	— .02	20 .87
IX	36 .56	+ .15	.71	21 .09	— .02	21 .07
	Mean,		128°17′36″.77	Mean,		19°47′20″.91
	Probable Error,		±.034	Probable Error,		±.028
	Proper Motion,		—0.063 ±0.009	Proper Motion,		+0.007 ±0.008

STAR 27.

Plate.	Right Ascension: At Epoch of Plate	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°17′52″.80	—0″.17	52″.63	20°06′36″.49	+0″.15	36″.64
II	.35	— .17	.18	.67	+ .15	.82
III	.56	— .16	.40	.50	+ .15	.65
IV	.71	— .16	.55	.43	+ .15	.58
V	.42	+ .08	.50	.70	— .07	.63
VII	.34	+ .08	.42	.73	— .07	.66
VIII	.30	+ .08	.38	.71	— .07	.64
IX	.39	+ .08	.47	.86	— .08	.78
	Mean,		128°17′52″.44	Mean,		20°06′36″.68
	Probable Error,		±.037	Probable Error,		±.022
	Proper Motion,		—0.035 ±0.010	Proper Motion,		+0.032 ±0.006

STAR 28.

Plate.	Right Ascension. At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination. At Epoch of Plate.	P. M	At Epoch 1875.0.
I	128°18′06″.53	—0″.19	6″.34	20°16′31″.01	+0″.07	31″.08
II	.26	— .19	.07	30 .96	+ .07	31 .03
III	.44	— .19	.25	30 .78	+ .07	30 .85
IV	.58	— .19	.39	30 .93	+ .07	31 .00
V	.21	+ .09	.30	30 .98	— .03	30 .95
VII	.03	+ .09	.12	30 .97	— .03	30 .94
VIII	.22	+ .09	.31	31 .08	— .03	31 .05
IX	.22	+ .09	.31	31 .06	— .04	31 .02
	Mean,		128°18′06″.26	Mean,		20°16′30″.99
	Probable Error,		±.030	Probable Error,		±.020
	Proper Motion,		—0.040 ±0.008	Proper Motion,		+0.015 ±0.006

STAR 29.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°18′40″.95	—0″.29	40″.66	20″.52	+0″.17	20″.69
II	40 .52	— .29	.23	.31	+ .17	.48
III	40 .87	— .29	.58	.40	+ .17	.57
IV	41 .08	— .29	.79	.37	+ .17	.54
V	40 .50	+ .14	.64	.48	— .08	.40
VII	40 .30	+ .14	.44	.71	— .08	.63
VIII	40 .50	+ .14	.64	.62	— .08	.54
IX	40 .38	+ .14	.52	.81	— .08	.73
	Mean,		128°18′40″.56	Mean,		20°37′20″.57
	Probable Error,		±.046	Probable Error,		±.030
	Proper Motion,		—0.062 0.012	Proper Motion,		+0.036 ±0.008

STAR 31.

Plate.	Right Ascension			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°19′12″.34	—0″.27	12″.07	19°59′06″.84	+0″.10	6″.94
II	12 .31	— .27	12 .04	6 .88	+ .10	6 .98
III	11 .93	— .27	11 .66	6 .93	+ .10	7 .03
IV	12 .18	— .27	12 .91	6 .64	+ .10	6 .74
V	11 .64	+ .13	11 .77	6 .94	— .05	6 .89
VII	11 .73	+ .13	11 .86	7 .02	— .05	6 .97
VIII	11 .95	+ .13	12 .08	6 .88	— .05	6 .83
IX	11 .83	+ .13	11 .96	7 .07	— .05	7 .02
	Mean,		128°19′11″.92	Mean,		19°59′06″.92
	Probable Error,		±.041	Probable Error,		±.027
	Proper Motion,		—0.057 ±0.011	Proper Motion,		+0.022 ±0.008

STAR 32.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°20′56″.93	—0″.28	56″.65	19°38′06″.20	+0″.03	6″.23
II	57 .02	— .28	.74	.35	+ .03	.38
III	56 .98	— .28	.70	.17	+ .03	.20
IV	57 .20	— .28	.92	.05	+ .03	.08
V	56 .51	+ .14	.65	.28	— .02	.26
VII	56 .61	+ .14	.75	.27	— .02	.25
VIII	56 .71	+ .14	.85	.11	— .02	.09
IX	56 .64	+ .14	.78	.32	— .02	.30
	Mean,		128°20′56″.76	Mean,		19°38′06″.22
	Probable Error,		±.026	Probable Error,		±.028
	Proper Motion,		—0.059 ±0.007	Proper Motion,		+0.007 ±0.008

STAR 33.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination. At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°22′30″.50	—0″.34	30″.16	19°40′09″.34	+0″.04	9″.38
II	30 .37	— .34	30 .03	.57	+ .04	.61
III	30 .14	— .34	29 .80	.34	+ .04	.38
IV	30 .53	— .34	30 .19	.32	+ .04	.36
VII	29 .92	+ .17	30 .09	.50	— .02	.48
VIII	30 .02	+ .17	30 .19	.29	— .02	.27
IX	29 .71	+ .17	29 .88	.57	— .02	.55
	Mean,		128°22′30″.05	Mean,		19°40′09″.43
	Probable Error,		±.048	Probable Error,		±.037
	Proper Motion,		—0.072 ±0.013	Proper Motion,		+0.009 ±0.010

STAR 34.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°23′08″.33	—0″.27	8″.06	20°09′37″.37	+0″.10	37″.47
II	8 .29	— .27	8 .02	.32	+ .10	.42
III	8 .33	— .27	8 .06	.30	+ .10	.40
IV	8 .49	— .27	8 .22	.36	+ .10	.46
V	7 .80	+ .13	7 .93	.44	— .05	.39
VII	8 .06	+ .13	8 .19	.58	— .05	.53
VIII	8 .08	+ .13	8 .21	.48	— .05	.43
IX	7 .88	+ .14	8 .02	.47	— .05	.42
	Mean,		128°23′08″.09	Mean,		20°09′37″.44
	Probable Error,		±.029	Probable Error,		±.012
	Proper Motion,		—0.058 ±0.008	Proper Motion,		+0.022 ±0.003

STAR 35.

Plate.	Right Ascension:			Declination.		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°25′03″.01	—0″.27	2″.74	20°42′28″.84	+0″.14	28″.98
II	2 .92	— .27	.65	28 .80	+ .14	28 .94
III	3 .04	— .27	.77	28 .86	+ .14	29 .00
IV	3 .01	— .27	.74	28 .82	+ .14	28 .96
V	2 .78	+ .13	.91	28 .86	— .07	28 .79
VII	2 .58	+ .13	.71	29 .12	— .07	29 .05
VIII	2 .59	+ .13	.72	29 .00	— .07	28 .93
IX	2 .41	+ .14	.55	29 .17	— .07	29 .10
	Mean,		128°25′02″.72	Mean,		20°42′28″.97
	Probable Error,		±.028	Probable Error,		±.025
	Proper Motion,		—0.058 ±0.008	Proper Motion,		+0.030 ±0.007

STAR 36.

Plate.	Right Ascension.			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°26′25″.18	—0″.45	24″.73	20°22′35″.73	+0″.16	35″.89
II	25 .14	— .45	.69	.67	+ .16	.83
III	25 .17	— .44	.73	.59	+ .15	.74
IV	25 .40	— .44	.96	.63	+ .15	.78
VII	24 .59	+ .22	.81	.96	— .08	.88
VIII	24 .54	+ .22	.76	.78	— .08	.70
IX	24 .54	+ .22	.76	.92	— .08	.84
	Mean,		128°26′24″.78	Mean,		20°22′35″.81
	Probable Error,		±.028	Probable Error,		±.022
	Proper Motion,		—0.095 +0.007	Proper Motion,		+0.033 ± 0.006

STAR 37.

Plate.	Right Ascension.			Declination		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°26′31″.81	—0″.28	31″.53	20°01′19″.38	+0″.05	19″.43
II	.61	— .28	.33	.56	+ .05	.61
III	.50	— .28	.22	.31	+ .05	.36
IV	.89	— .28	.61	.28	+ .05	.33
V	.28	+ .14	.42	.42	— .02	.40
VII	.29	+ .14	.43	.34	— .03	.31
VIII	.32	+ .14	.46	.49	— .03	.46
IX	.27	+ .14	.41	.58	— .03	.55
	Mean,		128°26′31″.43	Mean,		20°01′19″.43
	Probable Error,		±.032	Probable Error,		±.029
	Proper Motion,		—0.059 ±0.006	Proper Motion,		+0.011 ±0.008

STAR 38.

Plate.	Right Ascension			Declination		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°29′56″.44	—0″.21	56″.23	20°16′19″.07	+0″.08	19″.15
II	.48	— .21	.27	19 .16	+ .08	.24
IV	.66	— .21	.45	18 .93	+ .07	.00
VII	.17	+ .10	.27	19 .08	— .04	.04
VIII	.15	+ .10	.25	19 .17	— .04	.13
IX	.32	+ .10	.42	19 .24	— .04	.20
	Mean,		128°29′56″.32	Mean,		20°16°19″.13
	Probable Error,		±.031	Probable Error,		±.030
Proper Motion,			—0.045 ±0.008	Proper Motion,		+0.016 ±0.008

STAR 39.

Plate.	Right Ascension			Declination .		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°30′39″.00	—0″.35	38″.65	20°21′52″.34	+0″.07	52″.41
II	38 .72	— .35	.37	.34	+ .07	.41
III	38 .82	— .35	.47	.32	+ .07	.39
IV	39 .01	— .35	.66	.24	+ .07	.31
V	38 .44	+ .17	.61	.30	— .03	.27
VII	38 .33	+ .17	.50	.42	— .03	.39
VIII	38 .34	+ .17	.51	.38	— .03	.35
IX	38 .33	+ .17	.50	.56	— .04	.52
	Mean,		128°30′38″.53	Mean,		20°21′52″.38
	Probable Error,		±.027	Probable Error,		±.021
Proper Motion,			—0.075 ±0.008	Proper Motion,		+0.015 ±0.006

Star 40.

Plate.	Right Ascension: At Epoch of Plate	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°32′19″.74	—0″.42	19″.32	19°42′13″.48	+0″.05	13″.53
II	.92	— .42	.50	.60	+ .05	.65
III	.78	— .42	.36	.65	+ .05	.70
IV	.92	— .42	.50	.54	+ .05	.59
V	.14	+ .21	.35	.67	— .02	.65
VII	.22	+ .21	.43	.65	— .02	.63
VIII	.29	+ .21	.50	.61	— .02	.59
IX	.20	+ .21	.41	.61	— .02	.59
	Mean,		128°32′19″.42	Mean,		19°42′13″.62
	Probable Error,		±.020	Probable Error,		±.014
	Proper Motion,		—0.090 ±0.006	Proper Motion,		+0.010 ±0.004

Star 41.

Plate.	Right Ascension: At Epoch of Plate	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate	P. M.	At Epoch 1875.0.
VII	128°06′08″.44	+0″.10	8″.54	20°06′21″.68	—0″.03	21″.65
VIII	.30	+ .10	.40	.78	— .03	.75
	Mean,		128°06′08″.47	Mean,		20°06′21″.70

Star 42.

Plate.	Right Ascension: At Epoch of Plate	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
VII	128°38′00″.16	+0″.15	00″.31	20°06′16″.46	—0″.08	16″.38
VIII	59 .83	+ .15	59 .98	.29	— .08	.21
	Mean,		128°38′00″.14	Mean,		20°06′16″.30

STAR 43.

Plate.	Right Ascension. At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination. At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°39′47″.04	—0″.46	46″.58	20°19′06″.94	+0″.03	6″.97
II	46 .71	— .46	.25	.77	+ .03	.80
III	46 .88	— .45	.43	.72	+ .03	.75
IV	47 .05	— .45	.60	.56	+ .03	.59
V	46 .32	+ .22	.54	.68	— .02	.66
VII	46 .27	+ .22	.49	.82	— .02	.80
VIII	46 .32	+ .22	.54	.95	— .02	.93
IX	46 .06	+ .23	.29	.74	— .02	.72
	Mean,		128°39′46″.46	Mean,		20°19′06″.78
	Probable Error,		±.036	Probable Error,		±.035
	Proper Motion,		—0.097 ±0.010	Proper Motion,		+0.007 ±0.010

STAR 44.

Plate.	Right Ascension. At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination. At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°40′18″.28	—0″.23	18″.05	20°36′14″.23	+0″.07	14″.30
II	18 .27	— .23	18 .04	.33	+ .07	.40
III	18 .49	— .22	18 .27	.31	+ .07	.38
IV	18 .26	— .22	18 .04	.21	+ .07	.28
V	18 .05	+ .11	18 .16	.40	— .03	.37
VII	17 .95	+ .11	18 .06	.42	— .03	.39
VIII	17 .87	+ .11	17 .98	.36	— .03	.33
IX	18 .08	+ .11	18 .19	.33	— .04	.29
	Mean,		128°40′18″.10	Mean,		20°36′14″.34
	Probable Error,		±.027	Probable Error,		±.013
	Proper Motion,		—0.048 ±0.008	Proper Motion,		+0.015 ±0.004

STAR 45.

Plate.	Right Ascension			Declination:		
	At Epoch of Plate.	P. M	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
II	128°44′17″.78	—0″.33	17″.45	19°51′23″.45	+0″.08	23″.53
III	.62	— .33	.29	.38	+ .08	.46
IV	.98	— .33	.65	.22	+ .08	.30
V	.26	+ .16	.42	.44	— .04	.40
VII	.34	+ .16	.50	.56	— .04	.52
VIII	.39	+ .16	.55	.45	— .04	.41
IX	.23	+ .16	.39	.43	— .04	.39
	Mean,		128°44′17″.46	Mean,		19°51′23″.43
	Probable Error,		±.032	Probable Error,		±.022
Proper Motion,			—0.070 ±0.009	Proper Motion,		+0.017 ±0.006

The final results of the measurements have been collected on the next page; the right ascensions and declinations are obtained from α_1 and δ_1, which are printed in the foregoing pages in slightly bolder type, by adding the transformation corrections given in Table VI, page 239. The magnitudes are those of the Bonn Durchmusterung.

Catalogue of the Relative Positions and Proper Motions of 42 Stars in the Præsepe Group.

Mean Equinox of 1875.0. **Epoch 1875.0.**

Star.	Mag. B. D.	Right Ascension.	Proper Motion	Declination.	Proper Motion.	No. of Plates.
1	8.8	127° 35′ 27″.78	—0″.091	+20° 26′ 49″.70	+0″.032	8
2	8.2	36 26.49	— .066	+20 09 59.43	+ .031	8
3	8.4	37 30.81	— .081	+19 57 07.85	+ .002	7
4	7.2	39 11.48	— .061	+19 42 04.48	+ .002	8
5	8.0	47 35.08	— .030	+20 38 32.69	+ .037	8
6	8.4	51 32.17	— .069	+20 25 32.80	+ .044	8
7	9.0	54 07.49	— .071	+19 56 14.22	— .006	8
7A	8.9	57 57.87		+20 09 42.23		4
8	9.0	57 58.28	— .072	+ 20 26 12.42	+ .025	8
10	8.0	58 48.92	— .040	+20 06 50.24	+ .029	8
11	8.8	127 59 37.19	— .075	+20 01 46.74	+ .021	8
14	8.0	128 07 44.78	— .042	+20 31 29.12	+ .027	8
15	7.0	07 54.88	— .054	+20 13 01.32	+ .025	8
16	8.0	08 44 32	— .073	+19 42 50.04	+ .006	8
17	7.2	10 04.92	— .058	+19 48 46.88	+ .018	8
18	8.2	11 31.77	— .046	+19 59 31.59	+ .021	8
19	9.0	11 36.50		+20 35 50.69		5
20	8.2	11 51.24	— .042	+19 58 50.44	+ .016	8
22	7.0	12 43.14	— .068	+20 26 50.10	+ .027	8
23	7.3	15 00.34	— .049	+20 34 39.01	+ .040	8
23A	9.0	15 56.81	— .069	+20 26 02.88	+ .020	8
24	8.2	16 57.45	— .045	+19 58 19.04	+ .015	8
25	8.5	17 31.22	— .054	+20 07 36.50	+ .015	8
26	7.0	17 35.17	— .063	+19 47 20.68	+ .007	8
27	7.3	17 52.03	— .035	+20 06 36.40	+ .032	8
28	8.5	18 06.49	— .040	+20 16 30.70	+ .015	8
29	8.8	18 42.24	— .062	+20 37 20.21	+ .036	8
31	7.2	19 10.91	— .057	+19 59 06.57	+ .022	8
32	9.0	20 53.84	— .059	+19 38 05.83	+ .007	8
33	8.2	22 26.97	— .072	+19 40 08.90	+ .009	7
34	7.1	23 07.75	— .058	+20 09 36.79	+ .022	8
35	8.7	25 05.96	— .058	+20 42 28.08	+ .030	8
36	9.0	26 25.91	— .095	+20 22 34.83	+ .033	7
37	7.7	26 30.02	— .059	+20 01 18.46	+ .011	8
38	9.0	29 56.77	— .045	+20 16 17.75	+ .016	6
39	8.6	30 39.81	— .075	+20 21 50.91	+ .015	8
40	8.7	32 14.58	— .090	+19 42 12.03	+ .010	8
41	9.5	36 07.23		+20 06 19.46		2
42	9.3	37 58.79		+20 06 13.76		2
43	7.5	39 47.65	— .097	+20 19 03.89	+ .007	8
44	8.9	40 22.88	— .048	+20 36 11.29	+ .015	8
45	8.4	128 44 12.34	— .070	+19 51 19.77	+ .017	7

VI.

Discussion of Results.

Let us first ascertain what is the probable error of a measured coördinate, being careful not to let personalities in the observing enter into our result. Each coördinate was measured completely, that is in both the direct and in the reversed positions, by two observers. The difference between the two complete measurements will be free from personalities and may be ascribed to errors of observation. This difference, which I shall call v, may easily be computed from Table III; say the two observers are Schlesinger and Kretz, then subtract (*S*—*K*) *direct*, from (*S*—*K*) *reversed* and the difference is double the amount by which one observer's complete measurement differs from the other's, or $2v$. The probable error of a final coördinate is then given by,

$$\pm \frac{0.6745}{2}\sqrt{\frac{[vv]}{n}}$$

Proceeding in this way for all the plates we obtain the following probable errors. Only those stars were used, thirty-three in number, which appear on all the plates.

	Probable Error of a final x.	Probable Error of a final y.
Plate I	±0″ 034	±0″.031
II	.036	.029
III	.023	.023
IV	.024	.020
V	.020	.027
VII	.034	.020
VIII	.032	.025
IX	.037	.027
Means,	±0″.030	±0″.025

The greater uncertainty in right ascension is due to the fact that the images are usually elongated in that direction and are therefore more difficult to bisect. The elongation was caused by the failure of Rutherfurd's clock to keep pace exactly with the diurnal motion of the group, sometimes lagging slightly or sometimes moving too rapidly.

In the tabulation of results the probable error of each right ascension and declination is given. We may compute the probable error of right ascension of a star as derived from a single plate by the expression

$$\pm 0.6745\sqrt{\frac{[vv]}{264-66}}\cos\delta_0$$

where $[vv]$ is the sum of the squares of all the residuals in right ascension for the thirty-three stars which appear on all eight plates; the factor $\cos\delta_0$ serves to reduce the probable error to arc of a great circle. The expression for the probable error of a single declination is identical with the above except that $\cos\delta_0$ is omitted. In this way we obtain the probable errors,

In Right Ascension	In Declination.
±0″.081	±0″.058

If we do not confine ourselves to the thirty-three stars as above, but use all the stars, we get

±0″.080	±0″.060

Thus it appears that the uncertainty in a right ascension or in a declination is considerably greater than that in the corresponding measured coördinate. We may conclude from this that when a large number of plates is available, better results will be attained, for a given expenditure of time and labor, by measuring a large number of plates rather than measuring a few with all the elaboration used in the present research. But for the Rutherfurd photographs such elaboration is amply justified by the very limited number of existing photographs of so early a date.

It might appear at first as though a large part of the discrepancy between the two sets of probable errors, namely, those for the measured coördinates, and those for the resulting right ascension and declination, could be accounted for by the uncertainty of the constants used for the several plates. That such is not the case appears from the following considerations: the residuals for the five comparison stars, given on pages 247 and 248, exhibit a remarkable uniformity, showing that the greater part of these residuals is due to inaccuracies in the meridian observations. It follows, therefore, that the probable errors given for the constants p, r, k and c, are due not so much to errors in measuring the plate as to errors in the meridian places. To obtain more precise information on this point, let us correct the meridian places of each of the comparison stars by the mean of the residuals for that star, and suppose we have effected thes leat-square solutions anew, using now the corrected meridian places. It can easily be shown that the new solutions would lead to exactly the same values of the constants as had been first obtained, but now each residual will be altered by a certain quantity, namely, the amount of the corresponding correction to the meridian place. We may then subtract at once the mean of the residuals for a star, from the corresponding residual in each least-square solution and then compute the probable errors of the constants. The results of such a computation are as follows:

		Probable Error of p or r.	Probable Error of k or c
Plate	I	±0.000013	±0″.026
	II	24	.049
	III	16	.032
	IV	16	.032
	V	15	.030
	VII	08	.016
	VIII	11	.022
	IX	20	.041
Means,		±0.000015	±0″.031

The former means were

±0.000032 ±0″.065

and these must be regarded as indicating the uncertainty in the absolute values of the constants; if the constants which we have obtained are in error, then there will be a decided tendency to error in the same direction on *different* plates, and the smaller probable errors given above indicate how much we should expect the adopted values of the constants to differ from each other as obtained for different plates. Consequently only a small part of the discrepancy between the probable errors of the measured coördinates and of the right ascensions and declinations can be due to uncertainties in the adopted constants.

The discrepancy is probably caused by inaccuracies, and in some cases neglect, of instrumental corrections. For example, the difference between the two complete measurements of a coördinate is independent of errors in the determination of the division corrections, because the two observers always used the same lines; but not so with the differences of the right ascensions or declinations as derived from different plates. Similarly, the corrections for temperature and straightness of the scale, which we have neglected, do not affect the agreement of the measured coördinates. Possibly too, there have been distortions of the film, but the smallness of the probable errors on the whole must rather be taken as evidence against such distortions. It is important to note that the close agreement of the right ascensions and declinations for different plates affords a striking confirmation of the permanence of the Rutherfurd plates, which in the present case have been measured a quarter of a century after they were made.*

If we consider the probable errors of the measured coördinates, we see that the uncertainty is considerably greater upon some plates than upon others. Notwithstanding, equal weights have been assigned to all the plates, since it appears that the uncertainty in a measured coördinate forms only a small part of the uncertainty in the corresponding right ascension or declination.

Let us now compare the photographic results with those of the heliometer. In his memoir upon the group, Professor Schur has given the places of forty-five stars referred to the mean equinox and epoch of 1875.0, which are the same as those used in the present paper. Of these stars all but five appear on the photographs. The following table gives first the uncorrected or direct differences obtained by subtracting the right ascension, declination and proper motion of each star in our catalogue, from the corresponding quantities in Schur's. The differences in right ascension and in proper motion in right ascension have been multiplied by cos δ_0 to reduce them to arc of a great circle.

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*See, in this connection. "On the Permanence of the Rutherfurd Photographs," by Harold Jacoby, Annals of the N. Y. Acad. of Sciences, Vol. IX.

COMPARISON WITH HELIOMETER RESULTS.
HELIOMETER *minus* PHOTOGRAPHS.

Star.	Right Ascension.		Declination.		Proper Motion.		No. of Plates.
	Direct Diff's.	Corr'd. Diff's.	Direct Diff's.	Corr'd. Diff's.	Diff's in R As.	Diff's in Decl.	
	″	″	″	″	″	″	
1	—0.04	+0.07	+0.40	—0.08	+0.016	—0.015	8
2	— .03	— .02	+ .46	— .04	— .014	— .020	8
3	— .17	— .24	+ .61	+ .10	+ .011	+ .004	7
4	+ .24	+ .09	+ .73	+ .20	— .019	+ .005	8
5	— .15	+ .03	+ .67	+ .13	+ .021	+ .001	8
6	— .05	+ .06	+ .55	— .02	— .011	— .032	8
7	+ .12	+ .06	+ .67	+ .07	— .004	+ .018	8
8	— .11	+ .01	+ .50	— .10	— .004	— .020	8
10	+ .11	+ .12	+ .72	+ .10	— .030	— .022	8
11	— .01	— .03	+ .67	+ .04	+ .003	— .013	8
14	— .26	— .10	+ .74	+ .08	— .032	— .008	8
15	— .11	— .06	+ .52	— .15	— .019	— .008	8
16	+ .38	+ .25	+ .57	— .12	— .007	+ .001	8
17	+ .22	+ .18	+ .70	+ .01	— .017	— .019	8
18	+ .16	+ .13	+ .62	— .08	— .023	— .028	8
19	— .27	— .09	+ .71	+ .04			5
20	+ .03	.00	+ .66	— .04	— .035	— .022	8
22	— .20	— .07	+ .67	— .02	— .007	— .017	8
23	— .08	+ .04	+ .79	+ .09	— .020	— .031	8
24	— .06	— .09	+1.04	+ .31	— .016	— .011	8
25	— .02	.00	+ .62	— .10	— .016	— .011	8
26	+ .20	+ .10	+ .69	— .05	— .014	— .006	8
27	+ .08	+ .10	+ .87	+ .14	— .032	— .033	8
28	— .25	— .18	+ .68	— .04	— .028	— .014	8
29	— .51	— .31	+ .73	+ .02	— .004	— .026	8
31	+ .01	— .02	+ .80	+ .06	— .007	— .017	8
32	+ .32	+ .17	+ .80	+ .04	— .014	— .002	8
33	+ .07	— .07	+ .74	— .02	+ .009	— .011	7
34	+ .07	+ .11	+ .94	+ .19	+ .002	— .010	8
35	— .32	— .09	+ .66	— .08	— .009	— .026	8
36	— .13	— .02	+ .79	+ .03	+ .037	— .030	7
37	— .06	— .07	+ .68	— .10	— .001	— .006	8
38	— .05	+ .03	+ .93	+ .14	— .018	— .008	6
39	— .14	— .03	+ .77	— .02	+ .008	— .010	8
40	+ .08	— .04	+ .57	— .25	+ .028	+ .001	8
41	— .11	— .09	+ .78	— .05			2
42	— .23	— .20	+ .66	— .18			2
43	— .16	— .06	+ .91	+ .07	+ .031	— .002	8
44	— .11	+ .09	+ .71	— .12	— .017	.000	8
45	— .07	— .13	+ .58	— .30	+ .018	+ .011	7

The corrected differences in right ascension and declination were obtained by adding systematic corrections and also by modifying the scale-value and orientation of the photographs. That is, a least-square solution was made to determine how much the constants of the plates would have to be changed so as to secure the best possible agreement between the two catalogues. Each star gives two equations of the form,

$$Xdp + Ydr + dk + d\alpha = 0$$
$$Ydp - Xdr + dc + d\delta = 0$$

where $d\alpha$ and $d\delta$ are the uncorrected or direct differences in the table. The least-square solution may be carried out in a manner entirely similar to that previously used. The differences for stars 18, 20, 24 and 25 were not used because these stars were not included in Schur's triangulation, but each was merely located by position angle and distance from the nearest star in the triangulation. Stars 19, 41 and 42 were also excluded in making the least-square solution because of the small number of plates on which they appear. The remaining stars, thirty-three in number, give the following corrections to the contents:

$$\begin{aligned} dp &= +0.000011 \pm 0.000009 \\ dr &= +0.000098 \pm 0.000009 \\ dk &= +0''.047 \pm 0''.014 \\ dc &= -0''.667 \pm 0''.014 \end{aligned}$$

The probable error of one equation is

$$\pm 0''.080$$

a quantity which speaks well for the accuracy of all three researches concerned. The corrected differences in the table are now obtained by adding to each uncorrected difference

$X{\cdot}dp + Y{\cdot}dr + dk$ in the right ascensions,

and $Y{\cdot}dp - X{\cdot}dr + dc$ in the declinations.

From the above value for dp we see that the meridian observations gave a scale-value which agrees very closely with that obtained from the heliometer places; the largest effect that dp has on either coördinate of any star is only about 0''.02. On the other hand the value of dr, or the change in the orientation constant is quite large, corresponding to a correction of about 0''.20 in the coördinates of outlying stars. The meridian observations which we used to determine the orientation of the group, were also employed by Schur for the same purpose, and were found by him to give results which practically agreed with those obtained by an independent method. As we have adopted Schur's proper motions for the comparison stars, to reduce their places to the epochs of the plates, we can only conclude that the somewhat large value of *dr* is due to the fact that the relative positions of these stars with respect to the rest of the group have been differently determined by the photographs on the one hand, and the heliometers on the other. This explanation is borne out by the comparatively large values of the corrected differences for the comparison stars, numbers 4, 5, 15, 40 and 44.

The large value for *dk*, or the systematic correction in declination, was to be expected. We have already remarked (see page 236) that the proper motions used for the comparison stars were not derived by Schur from the direct differences between the two heliometer determinations of the places of these stars, but that systematic corrections,

$$+0^s.0003 \text{ and } -0''.039$$

were added to the proper motions in right ascension and declination respectively. Hence we must expect the photographic places to differ from those of the heliometer for the epoch of 1875.0, by

$$+0''.071 \text{ and } -0''.612,$$

the proper motion having been used for an interval of 15.7 years. These corrections agree quite well with the values of *dk* and *dc* respectively, as obtained above.

VII.

Orientation by Trails. Scale-Value.

An independent method for orienting a stellar photograph is furnished by the "trails" or third images of some of the brighter stars. The Rutherfurd photographs previously reduced depend upon this mode of orientation, and the present research offers an admirable opportunity for testing its accuracy. Four trails have been measured and reduced on each Præsepe plate, and the resulting values of the orientation corrections were compared with the results obtained from a comparison with meridian observations, and also with those obtained with the use of the heliometer places. On Plate II the trails were too faint to admit of measurement, and on Plate V they were missing altogether.

The trails were measured in a different manner from that used for the other images. The plate was first set in the position which it occupied when "*y* direct" had been measured for the stars, and the micrometer was set and read on the east image of a star whose trail was to be measured. Then, without touching the microscope, the plate was moved along the cylinder till the corresponding trail came into view. This was always possible because the plate had been approximately oriented when first set in the machine. Two readings were made upon the trail and the plate was then moved back to the east image, which was read a second time. The same operations were gone through for the west image, and the mean of all the readings on the images was subtracted from the mean of the readings on the trail, thus giving the *offset* in declination by which the trail differed from the middle point between the two images. All the above operations were repeated in the opposite position of the plate, namely that corresponding to "*y* reversed," except that in the latter case the mean of the readings on the trail was subtracted from that for the images, so as to get the same sign for the offset as before. Each trail was thus measured by two observers separately, so that in all, sixteen readings were made on each trail, and eight upon each of the images. The resulting offsets are tabulated below in millimetres.

TRAIL MEASUREMENTS.

Plate. \ Star.	15.	22.	23.	27.	31.	37.
I	—.0443		—.0193		—.0084	+.0183
III	—.0676		—.0404	—.0398	—.0292	
IV	—.0535		—.0312		—.0169	+.0070
VII	—.0772	—.0422	—.0499		—.0294	
VIII	—.1054	—.0766	—.0718		—.0510	
IX	—.0850		—.0568		—.0356	—.0070

The distance from each trail to the middle point between the corresponding images was measured approximately as follows, being practically the same for all the stars upon a plate :

Plate,	I	III	IV	VII	VIII	IX	
s,	35.0,	35.1,	35.0,	39.3,	48.1,	39.4	millimetres.

We shall now consider what corrections must be applied to the above offsets in order that the true orientations of the plates may be computed from them.

Instrumental Corrections. The only correction of this kind is that for rotation, the data for which have already been given in Table II. Using the same notation as before the correction to the offset is

$$-s.\ i.\ \sin 1''$$

which is the same for all four stars. Having applied this connection, the offset may now be converted into seconds of arc by multiplying by the approximate scale value, 52.87.

Transformation Corrections. For the present purpose it will be convenient to use Ball and Rambaut's formulas quoted on page 238, in which $X \sec \delta_0$ and Y appear in the second members instead of $\Delta\alpha$ and $\Delta\delta$. We need only the second of these formulas :

$$\Delta\delta - y = -\tfrac{1}{4}\,(X \sec \delta_0)^2 \sin 2\delta_0 - \tfrac{1}{3}\,Y^3 - (X \sec \delta_0)^2\,Y$$

For the trail, $X \sec \delta_0$ is diminished by

$$z = 52.87 \cdot s \cdot \sec \delta_0,$$

while Y remains practically unchanged. Hence the correction to the offset is,

$$+\tfrac{1}{4} \sin 2\delta_0 \cdot z \cdot (z - 2X \sec \delta_0) + z\ (z - 2X \sec \delta_0)\ Y$$

Refraction Corrections. The trails were taken somewhat later than the principal images of the group, and as the zenith distance changed in the interval, the refraction-coefficients will also be changed. Denoting by M_y' and N_y' what these coefficients become for the trails, we have the correction to the offset,

$$M' \cdot z + (M_y - M_y')\,X \sec\delta_0 + (N_y - N_y')\,Y$$

The first term is constant for all four stars, and the two remaining terms are small. To calculate M_y' and N_y' we must know how much the hour angle has changed in the interval between the exposures for the principal images and that for the trail. As each of the former lasted six minutes and as the exposure for the trail was much shorter, we may safely adopt seven minutes of time as the change in the hour-angle. M_y' and N_y' may then be calculated with sufficient accuracy by interpolating in Table VII.

After these corrections have been applied it will be convenient to transform the offsets into position angles, which may be done by the formula

$$p = 270^\circ + \sin^{-1}\left\{\frac{\text{offset}}{z \cos\delta_0}\right\}$$

Precession, Nutation and Aberration. Formulas for correcting position angles for these were deduced in convenient form by Bessel* ; let

$$\alpha' = 20'' \sec\delta_0 \sin\alpha_0$$

$$\beta' = \sec\delta_0 \cos\alpha_0$$

$$\gamma' = \tan\delta \cos\alpha_0$$

$$\delta' = \tan\delta_0 \sin\alpha_0$$

$A, B, C, D =$ Bessel's star-numbers, tabulated for each day in the year in the ephemerides.

The true position angle at the beginning of the *same* year is found by adding to the observed position angle the correction,

$$(-A\alpha' + B\beta' + C\gamma' + D\delta')$$

Then to reduce this to beginning of *another* year we add

$$+\,20''.06 \sec\delta_0 \sin\alpha_0 \cdot t$$

where t is the integer corresponding to the difference of the years, and must be considered positive if we are reducing an observation to a later year than that in which it was made.

As an example of the reduction of trail measurements, I have set down the calculations in detail for the trail of Star 23, Plate I.

---

* "Astronomische Untersuchungen" Vol. I., pg. 202.

Offset,	— 0.0193	millimetres
Rotation Corr'n.,	+ 0.0005	
	— 0.0188	

In arc,	— 0″.99
Transf. Corr'n.,	+ 1 .75
Refraction	+ 0 .24
Corrected offset	+ 1″.00

Position Angle,	270 + 111″.9
—$(A\alpha' + B\beta' + C\gamma' + D\delta')$,	+ 2 .6
20.06″ sec δ_0 sin α_0 ·t,	+ 84 .0
True Position Angle,	270° + 198″.5

Consequently we have from this star,

$$r = + 0.000963$$

Similar calculations for all the trails gave the following results in which r has been multiplied by 10^6 throughout.

ORIENTATION BY TRAILS. VALUES OF $r \times 10^6$.

Star. / Plate.	15	22.	23	27.	31.	37.
I	+954		+963		+840	+873
III	+334		+390	+118	+288	
IV	+851		+777		+757	+706
VII	—128	+186	—140		— 52	
VIII	+122	+152	+111		+113	
IX	—360		—341		—248	—254

Taking the mean for the four stars on each plate and setting down again the values of r previously obtained by comparison with the meridian observations, we have,

	Orientation by Trails	Orientation by Merid. Obs.
Plate I	+ 0.000908	+ 0.001054
III	+ 282	+ 409
IV	+ 773	+ 1435
VII	— 34	— 35
VIII	+ 124	+ 211
IX	— 301	— 326
Means	+ 292	+ 458

In comparing these it will be remembered that a difference of 0.000100 corresponds to about 0″.20 in the coördinates of the outlying stars of the group. The results are decidedly adverse to the accuracy of this mode of orientation, especially as a comparison with the heliometer places indicates a further correction of

$$+0.000098$$

to the orientations obtained by using the meridian places. The large discrepancies are probably due to jarring of the plate during exposure, caused by stopping and starting the clock-work several times; the large difference for Plate IV admits of no other obvious explanation.

Let us now examine the scale-values of the different plates. The values of p given at the beginning of Section V include aberration and temperature effects. Formulas for the former correction are thus given by Bessel :*

$$\gamma = -(\cos \delta_0 \sin \alpha_0 + \tan \omega \sin \delta_0)$$
$$\delta = +(\cos \delta_0 \cos \alpha_0)$$

Then the true distance is found by adding to the observed distance s,

$$-s(C\gamma + D\delta),$$

C and D being as before, the Besselian star numbers.

We may also correct the values of p for the temperature at which the plates were measured by adding

$$+0.0000017\ (T - 65^\circ),$$

T being the temperature in Fahrenheit degrees at which the plate was measured, given in Table II. This expression is easily derived from the value of v on page 223. Corrections for the temperature at which the plate was exposed ought also to be applied, but sufficient data to establish a connection between this quantity and the scale-value are lacking. After a greater number of Rutherfurd's photographs have been reduced we may have more definite information on this point.

The true scale-value S (so far as it can be obtained without the last correction), is given thus,

$$S = 52''.87\ [1 + p - C\gamma - D\delta + 0.0000017\ (T^\circ - 65^\circ)]$$

The following table gives the corrections and the resulting scale value for each plate. The corrections for temperature are very small and might well have been neglected. The last two columns give the readings of the thermometer attached to the telescope and of the "focus," which have been copied from Table I for convenience of reference.

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* "Astronomische Untersuchungen," Vol. I, page 208.

SCALE-VALUE.

Plate.	Cor. for Aberration.	Cor. for Temp.	Corrected Scale-Value.	Tel. Therm.	Focus.
I	—0.000099	0.000000	52.8701	+58°	8.4
II	— 99	+ 2	52.8715	58	8.4
III	— 100	— 3	52.8712	53	8.4
IV	— 100	+ 4	52.8760	53	8.4
V	— 98	+ 3	52.8788	48	7.8
VII	— 99	— 2	52.8827	58	7.7
VIII	— 99	— 5	52.8831	58	7.7
IX	— 98	— 2	52.8840	48	7.8

The mean of the scale-values is

$$52''.8772$$

and if we adopt the correction of + 0.000009 as indicated by comparison with the heliometer places, this becomes

$$52''.8776.$$

However, either of these must still be regarded as only an approximate value, since the separate values for the different plates, as given above, vary in a way that cannot be fully explained by a connection with the readings either of the telescope thermometer or of the "focus."

The above investigations on the orientation and on the scale-value lead to the same conclusion; it will usually be better to determine all the constants of a plate by comparing the measures of some of the stars with their positions as known through meridian observations or otherwise, than to attempt to reduce them by means of a predetermined scale-value and orientation. In any case it is necessary to appeal to such known positions to determine the values of k and c, or the absolute place of the group in the sky. The positions of two stars are theoretically sufficient to determine all four constants, but in most cases it will be possible to find enough stars to eliminate errors of observation to a large extent.

In conclusion, I wish to acknowledge my indebtedness to Messrs. Kretz and Hays for assisting me in the measurement of the plates, and to Professor Jacoby, who has kindly explained to me the methods used by him in the measurement and reduction of stellar photographs, and who has also suggested some improvements in the paper in reading over the proofs. Finally I desire to express my thanks to Professor Rees, Director of the Observatory, for the interest he has shown in my work, and for securing its publication.

Note on Refraction Formulas for Photographic Plates.

Formulas for correcting the measured rectangular coördinates of a star upon a photographic plate for refraction, may be easily derived from the well known general formulas of Bessel. On page 166, Vol. 1. of his "Astronomische Untersuchungen" he gives the following corrections to the differences of right ascension and declination:

$$\Delta\,(\alpha' - \alpha) = s\cdot k\,[\tan^2\zeta\cos(p - q)\sin q - \tan\zeta\sin q\tan\delta_0\cos p + \sin p]\sec\delta_0$$

$$\Delta\,(\delta' - \delta) = s\cdot k\,[\tan^2\zeta\cos(p - q)\cos q + \tan\zeta\sin q\tan\delta_0\sin p + \cos p]$$

Substituting

$$X = s\sin p$$
$$Y = s\cos p$$
$$G = \tan\zeta\sin q$$
$$H = \tan\zeta\cos q$$

we obtain

$$\Delta\,(\alpha' - \alpha) = k\,X\sec\delta_0\,(I + H^2) \quad + k\,Y\,(G - \tan\delta_0)\,H\sec\delta_0$$
$$\Delta\,(\delta' - \delta) = k\,X\,(G + \tan\delta)\,H \quad + k\,Y\,(I + G^2)$$

These formulas become identical with those of Professor Jacoby when we change k into β in order to allow for the increased refrangibility of photographic rays.

One point in the above deduction deserves mention; the quantities δ_0, etc., were intended by Bessel to be the means of corresponding quantities for the two stars whose distance along the arc of the great circle joining them has been measured. We have treated them as though they referred to one end of that arc; however, this merely amounts to neglecting terms in the second and higher powers of s, which may be done for most photographic plates.

If we omit the middle term in each bracket in Bessel's formulas we obtain the formulas given by Professor Turner; the omission of these terms, as has been repeatedly pointed out, corresponds to a rotation of the axes, and is, therefore, of no importance when we determine the constants of a plate by comparing the measured coördinates of some of the stars with their known places. Turner's formulas are

$$\begin{aligned}\Delta X &= kX \cdot (1 + H^2) + kY \cdot GH \\ \Delta Y &= kX \cdot GH \quad + kY \cdot (1 + G^2)\end{aligned}$$

These formulas may be simplified when we use the above method for determining the constants, as I pointed out in the *Astronomical Journal*, No. 430; rejecting so much of the correction for refraction as may be regarded as either an orientation correction or a scale-value correction, we have remaining

$$\begin{aligned}\Delta X &= kX \cdot (H^2 - G^2) \\ \Delta Y &= kX \cdot 2GH\end{aligned}$$

These formulas might have been used for the reduction of the Præsepe plates, but as we wished to know the true orientation and scale-value for each plate, extra corrections to these constants would have been necessary. Only four of the comparison stars used need corrections for refraction; so that in the present case nothing would have been gained by the use of the last formulas. When, however, the number of comparison stars is greater, or when we do not care especially to know the true orientation and scale-value of a plate, these formulas will save some labor.

. GENERAL INDEX TO VOLUME X.

Names of authors are in **heavy face type**. Generic and specific names in *italics*.

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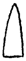

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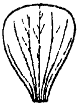

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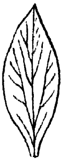

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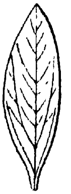

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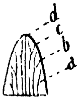

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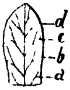

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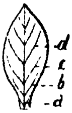

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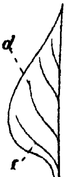

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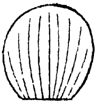

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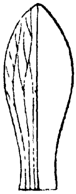

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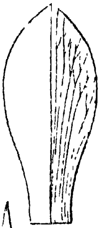

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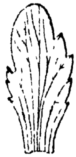

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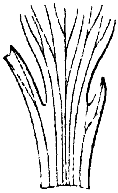

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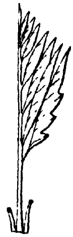

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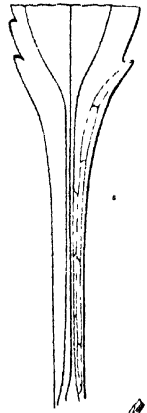

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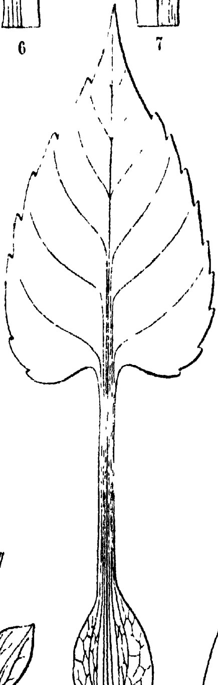

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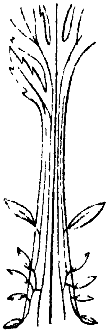

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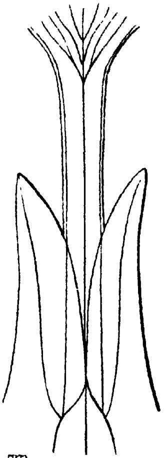

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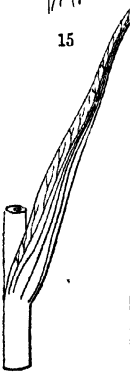

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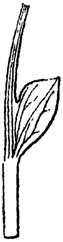

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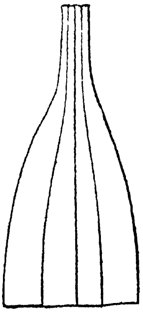

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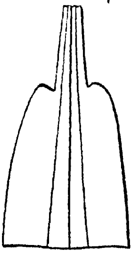

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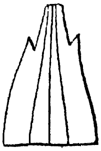

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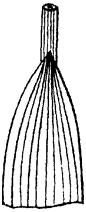
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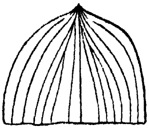
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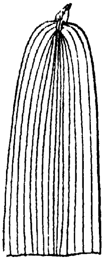
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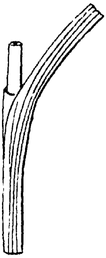
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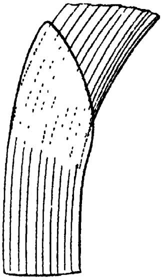
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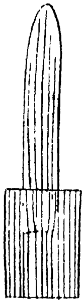
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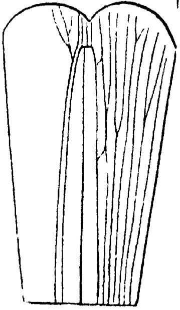
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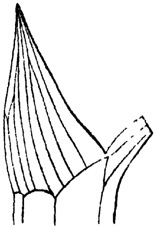
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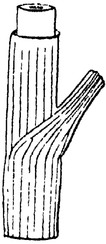
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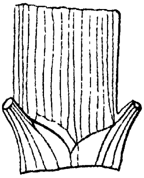
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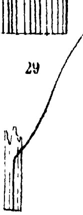
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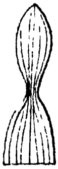
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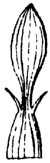
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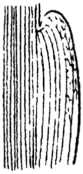
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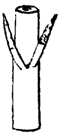
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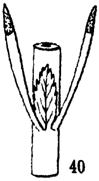
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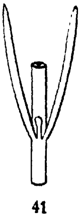
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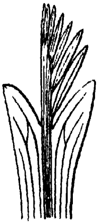
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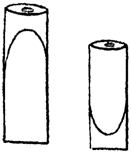
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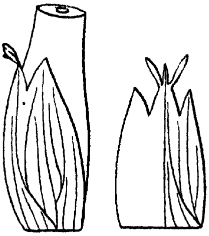
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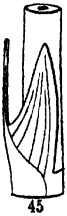
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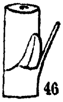
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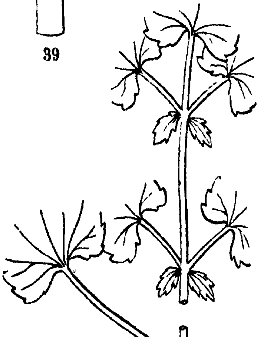
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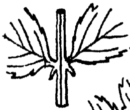
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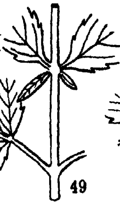
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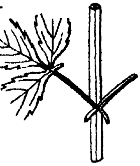
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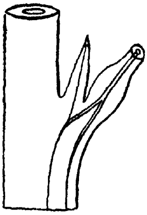
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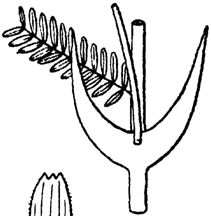
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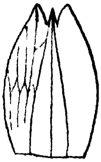
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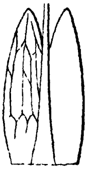
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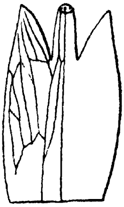
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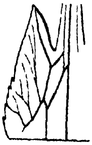
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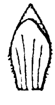
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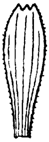
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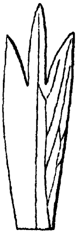
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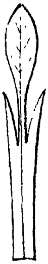
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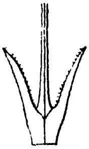
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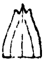
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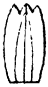
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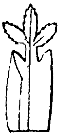
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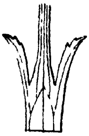
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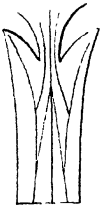
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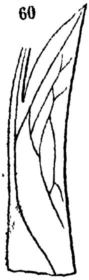
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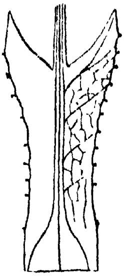
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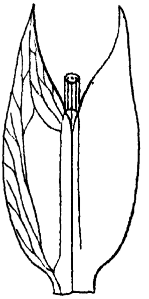
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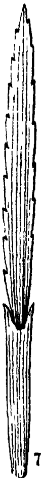
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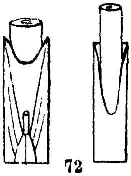
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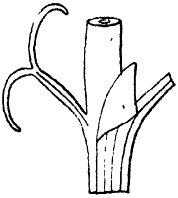
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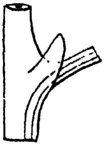
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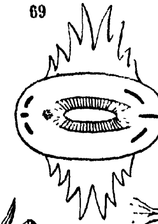
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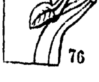
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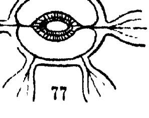
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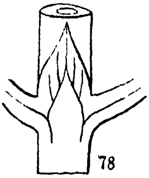
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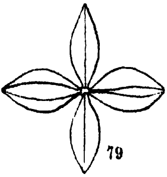
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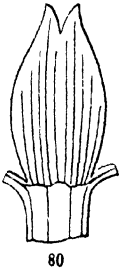
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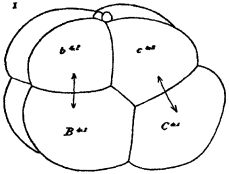

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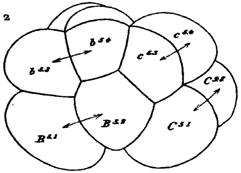

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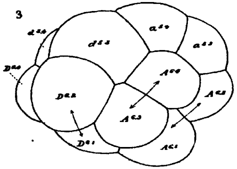

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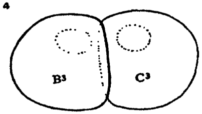

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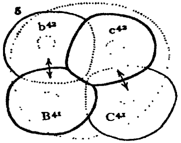

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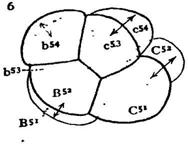

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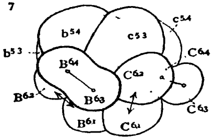

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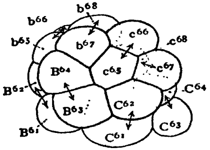

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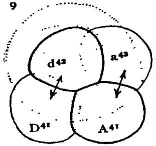

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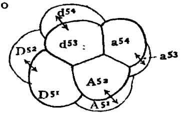

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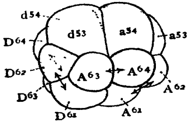

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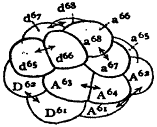

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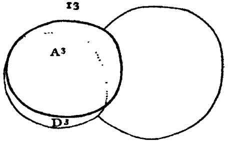

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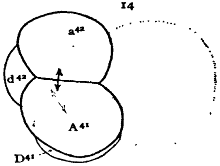

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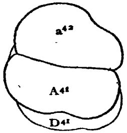

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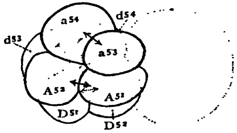

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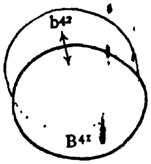

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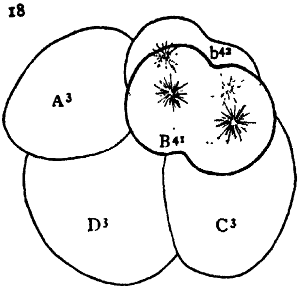

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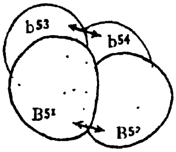

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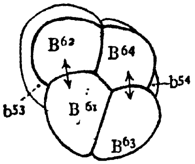

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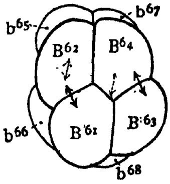

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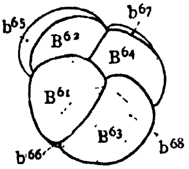

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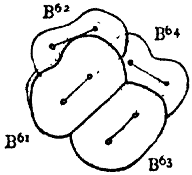

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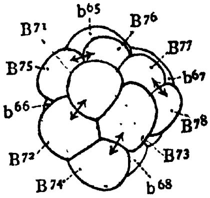

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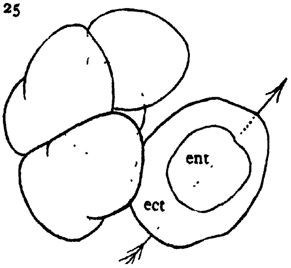

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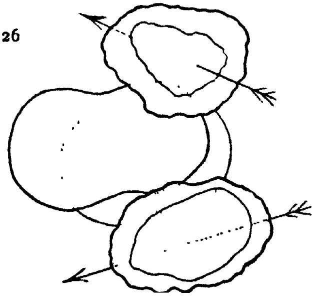

ANNALS

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1898.

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SESSION, 1898-1899.

The Academy will meet on Monday evenings at 8 o'clock, from October 3d to May 22d, in the rooms of the American Society of Mechanical Engineers, at **12 West 31st Street.**

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NOTE REGARDING PUBLICATIONS

OF THE

NEW YORK ACADEMY OF SCIENCES.

Publication of the **Transactions** of the Academy is discontinued with the issue of Volume XVI, 1898. The matter heretofore printed in the Transactions will be incorporated in the Annals.

The **Annals** (8vo), beginning with Volume XVI, will appear with new forms of typography and arrangement of matter; many changes having been made in the endeavor to facilitate the use of the volume for reference purposes. A volume of the Annals will hereafter coincide with the calendar year and will be issued in three parts. The price per volume is three dollars.

The **Memoirs** in quarto form will be published at irregular intervals. Part I of Volume I has been issued.

[ANNALS N. Y. Acad. Sci., XI., No. 1, pp 1–27, March 30, 1898.]

CONSIDERATIONS ON CELL-LINEAGE AND ANCESTRAL REMINISCENCE,

BASED ON

A RE-EXAMINATION OF SOME POINTS IN THE EARLY DEVELOPMENT OF ANNELIDS AND POLYCLADES.

EDMUND B. WILSON.

(Read December 13, 1897.)

FIVE years ago I observed in the embryos of two polychætous annelids, *Aricia fœtida* (Clap.) and *Spio fulginosus* (Clap.), that the two so-called "primary mesoblasts" bud forth a pair of extremely minute superficial cells near the posterior lip of the blastopore before giving rise to the mesoblast-bands.[1] Scarcely larger than polar bodies, these cells lie at or near the surface at the posterior margin of the entoblast-plate, wedged in between the latter and the primary mesoblasts (Fig. 1, *A*, *C*, *c*; Fig. 2, *A*, *c*, *c*); and in this position they are carried into the interior during the ensuing invagination. I could not determine their fate, and found no evidence that they underwent growth or division, or that they took any part in the building of the embryo. In *Nereis*, however, I found that this pair of rudimentary cells was represented by a group of not less than six or eight somewhat larger cells (Fig. 1, *B*, *D*; Fig. 2, *B*), formed in exactly the same way and in the same position,[2] and further that these cells were functional in development, giving rise to a definite part of the body, though, as will appear beyond, I fell into error regarding their precise fate.[1] These facts strongly suggested that the pair of rudimentary cells in *Aricia* and *Spio* were to be regarded as vestiges of an ancestral type of development in which they were represented by a group of larger functional cells, such as are still found in the embryo of *Nereis.* Such a conclusion, if it could be established, would possess an importance for the general problems of cell-lineage even greater than its interest for the more special problems of annelid embryology. For if vestigial structures may appear in ontogeny in the form of single cells, the fact would not only afford a striking illustration of the inadequacy of all so-called "mechanical" explanations of cleavage-forms, but would supply a very important datum for the estimation of the cell-theory as applied to development.

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[1] 1892, p. 458.

[2] 1892, p. 411.

The results of a re-examination of the history of these small cells in *Nereis*, taken in connection with other recent studies in cell-lineage, lend strong support to the conclusion indicated above, enabling us, as I believe, to give a definite interpretation to the vestigial cells of *Aricia*, *Spio* and other forms in which they have recently been observed;[2] and they also raise some interesting further questions regarding ancestral reminiscence in cell-lineage. I am also able to contribute some new observations on the cell-lineage of a polyclade (*Leptoplana*), which bear directly on these questions and considerably extend their range.

---

[1] Von Wistinghausen (1891) had previously observed in *Nereis Dumerilii*, a group of small cells derived from the "second somatoblast," which probably correspond with those I have described in *N. limbata* and *N. megalops*, though their exact origin was not followed. Wistinghausen believed that they gave rise to a part of the ectoblast—a result wholly different from both my earlier account and the present one.

[2] Minute cells exactly corresponding in origin and number to those of *Aricia* have been found by Mead in *Amphitrite* (1894, p. 467; 1897, p. 247) and by Holmes in *Planorbis* (1897, p 101). Lillie has found a pair of corresponding but slightly larger cells in *Unio* (1895, p. 27), while in *Clymenella* they are as large as the primary mesoblasts (Mead, 1897, p. 264) The corresponding cells in *Umbrella* (Heymons), *Crepidula* (Conklin), and *Physa* (Wierzejski) will be referred to beyond (see pp. 6, 11–12).

I.

THE RELATIONS BETWEEN MESOBLAST AND ENTOBLAST IN ANNELIDS AND MOLLUSKS.

In *Nereis*, as in the typical development of other annelids and of gasteropods and lamellibranchs, the mesoblast-bands are derived from the posterior cell of the fourth quartet of "micromeres."[1] This cell, now generally known as the *second somatoblast*, divides into two symmetrical halves which have been usually designated as the "primary mesoblasts;" and from them, by a series of slightly unequal successive divisions, arise the mesoblast-bands which extend forward in the cleavage-cavity at the sides of the embryo. Before giving rise to the mesoblast-bands, however, the "primary mesoblasts" bud forth the small cells already referred to, at or near the surface directly behind the two posterior macromeres "C" and "D." At least six, and probably not less than ten, of these cells are formed, the primary mesoblasts meanwhile sinking below the surface and becoming quite covered by ectoblast-cells which advance from the sides and from behind. The small cells first formed lie at the surface, wedged in between the "primary mesoblasts" and the macromeres (Fig. 1, *D*, *e*; Fig. 2, *B*,). Those formed later lie below the surface, owing to a change in the plane of division (Fig. 3, *A*). The small cells, which are very conspicuous in sections by reason of their intensely chromatic, closely reticulated nuclei, thus become arranged in a thin plate extending inwards from the surface between the primary mesoblasts and the two posterior macromeres (Fig. 3, *B*). After the formation of the small cells the divisions of the primary mesoblasts suddenly change both in form and direction, the plane of division being now nearly or quite at right angles to the former (*i. e.*, approximately parallel to the sagittal plane of the embryo) and the cells thus produced being nearly as large as the primary

---

[1] *Nereis* is somewhat exceptional in the fact that the other three cells of the fourth quartet are suppressed. In *Aricia*, *Polymnia*, *Spio*, *Pysgmobranchus*, *Hydroides*, *Polygordius* (all of which I have examined), and in some others, the fourth quartet, is complete, and in the first two forms named, a fifth quartet of (entoblastic) micromeres is formed before the invagination (Cf. Fig. 2, *A*).

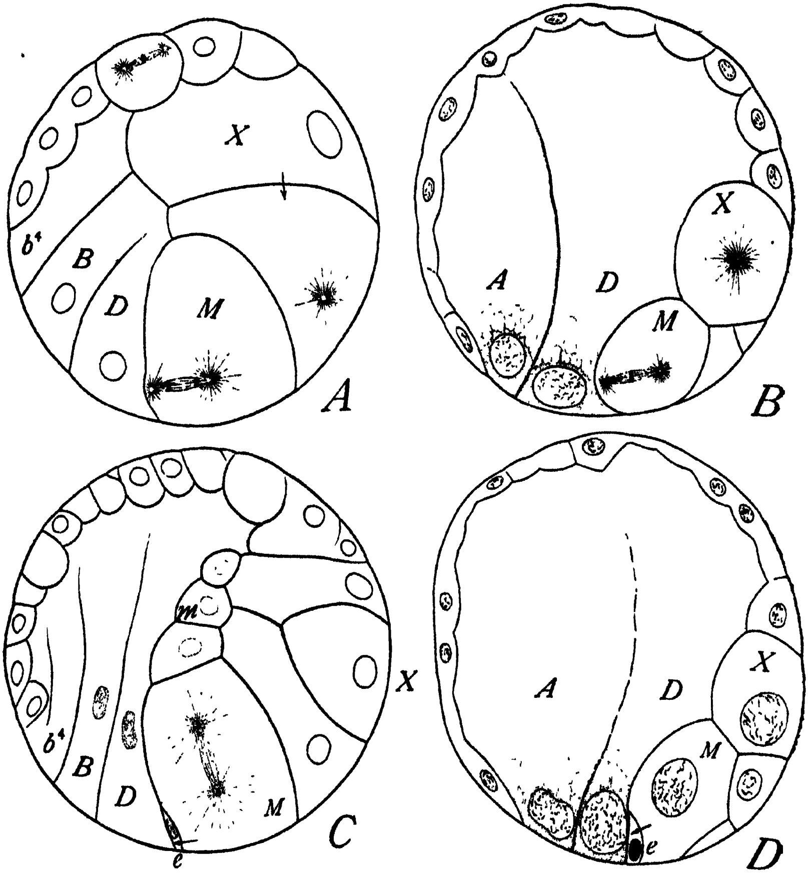

FIG. 1.[1] Early embryos of *Aricia* (***A***, ***C***) and *Nereis* (***B***, ***D***) in sagittal section (***A***, ***B***, ***C***, optical, ***D***, actual). Showing the formation of small posterior entoblasts (*e*) between *M* and *D*.

A, *B*, *D*, b^4, cells of the entoblast-plate (cf. Fig. 2); *M*, the "primary mesoblast;" *m*, mesoblast-band; *X*, the first somatoblast or its derivatives, forming the somatic plate.

mesoblasts. Thus are formed the mesoblast-bands which form together a V-shaped mass of cells lying between the macromeres and the overlying ectoblast. Near the middle line the two halves of the V are often slightly separated; and into the space thus formed some of the small cells usually extend, appearing in sections in the sharpest contrast both to the large rounded mesoblast-cells and to those of the lateral ectoblast (Fig. 3, *C*). From this point the mesoblast-bands extend towards the sides and ultimately curve upwards (forwards with respect to the adult long axis) at the sides of the embryo.[1]

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[1] All the figures are from camera drawings, made from preparations unless otherwise stated. Optical sections have been fully confirmed by actual.

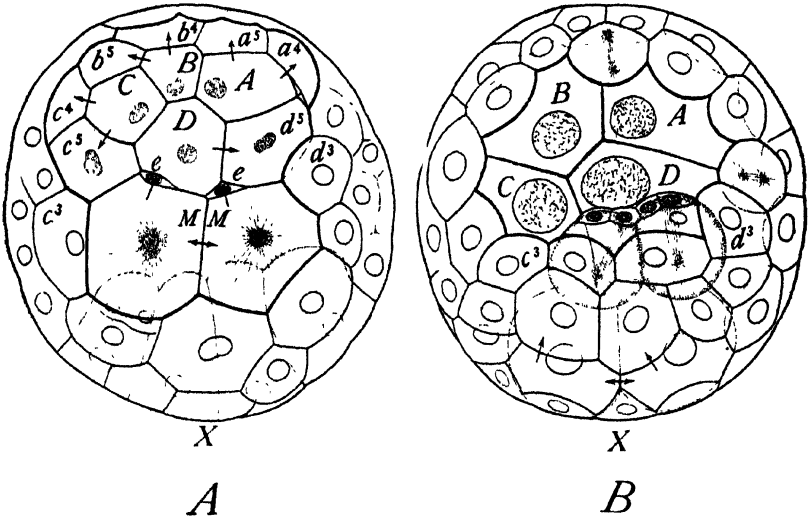

FIG. 2. Corresponding surface views, from the lower pole, of early embryos of *Aricia* (**A**) and *Nereis* (**B**); the limit of the ectoblast, *i. e.*, the lip of the blastospore, is shown by the heavy line. **A** shows the single pair of vestigial entoblasts (*e*, *e*) of *Aricia* lying in front of the primary mesoblasts which are dividing to form the mesoblast-bands (cf. Fig. 1, **C**, which shows the same specimen in sagittal section). **B** shows two pairs of superficial entoblasts, lying behind the macromere *D*, and the spindles of a deeper budding of the "primary mesoblasts" (cf. Fig. 3, **A**, for section of this stage).

A, *B*, *C*, *D*, the four basal entoblasts or macromeres; a^4–c^4, the fourth quartet of "micromeres" (entomeres); a^5–d^5, the fifth quartet (entomeres); c^3–d^3, derivatives of the third quartet (ectomeres); *M*, *M*, the primary mesoblasts (shaded in **B**).

Up to this point the account here given is substantially the same as that contained in my earlier paper on *Nereis*. Regard-

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[1] In *Aricia* the mesoblast-bands are formed much earlier, while the primary mesoblasts still lie at the surface (Fig. 1, *C*); and they lie at first side by side, nearly parallel to each other, extending upwards behind the entoblast-plate (Fig. 7). In both these respects *Aricia* is somewhat similar to *Lumbricus* (Cf. Wilson, Embryology of the Earthworm, Fig. 30: *Journ. Morph.*, 1889).

ing the fate of the small cells, however, my first account was wide of the mark; for I believed that they migrated into the interior and spread out upon the walls of the archenteron to form a part of the splanchnic mesoblast.[1] I accordingly called the small cells "secondary mesoblast" and applied the same term to the rudimentary cells of *Aricia* and *Spio.* Later studies by several observers seemed to confirm this conclusion. Lillie found in *Unio* a single pair of small superficial cells, budded forth from the "primary mesoblasts" exactly as in *Aricia* or *Nereis*, but relatively larger, which he likewise believed to wander into the cleavage-cavity to form a part of the mesoblast.[2] Heymons found in *Umbrella* two pairs of corresponding but still larger cells, which he, too, apparently traced into the mesoblast.[3] Mead found that a corresponding pair of minute cells, in *Amphitrite* are carried in at the tips of the mesoblast-bands;[4] while Holmes still more recently states that in *Planorbis* they enter the segmentation cavity.[5] Wierzejski's recent observations on *Physa*,[6] though differing from the foregoing in some important details, agree in referring the small cells, of which several pairs are formed, to the mesoblast. With such an array of confirmatory evidence my original conclusion seemed to be strongly supported. Conklin, however, in his remarkable paper on *Crepidula*, reached a wholly different result, finding in that gasteropod that cells which probably correspond with the small cells of *Nereis*, *give rise to the posterior part of the archenteron.*[7] In regard to *Nereis*, I have long suspected that my original account of the fate of the small cells was erroneous. A renewed examination of the matter has left no doubt that such was the case, and gives the strongest ground for the conclusion that, like the corresponding cells in *Crepidula*, *they enter into the formation of the archenteron.* The evidence for this conclusion is as follows:

In my earlier paper on *Nereis* I overlooked the fact that, besides the small cells derived from the "primary mesoblasts," other closely similar cells are formed, just in front of them *by budding from the macromeres.* These cells agree closely with those derived from the "primary mesoblasts" both in size and in the close reticulation and intensely chromatic character of

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[1] *Nereis*, p. 413.

[2] 1895, p. 28.

[3] 1893, p. 281.

[4] 1897, p. 248.

[5] 1897, p. 101.

[6] 1897, p. 389.

[7] 1897, p. 71.

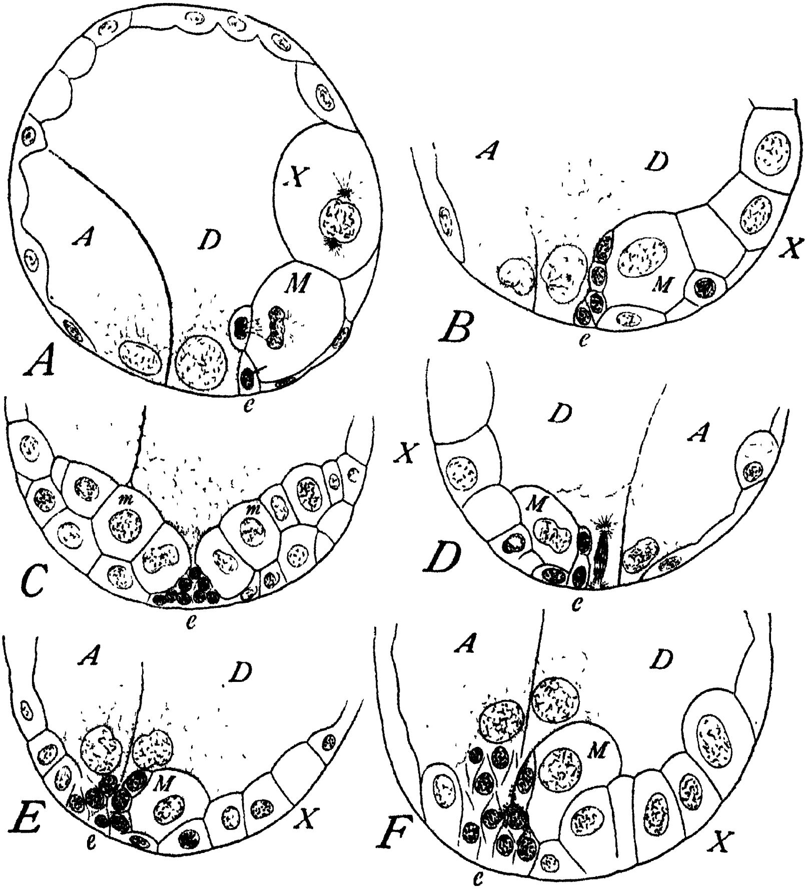

FIG. 3, NEREIS. Sections of successive stages in the formation of the entoblast-plug and mesoblast-bands in embryos of *Nereis* (actual sections, Flemming's fluid; ***C*** is tranverse, the others sagittal). Lettering as before. ***A*** shows a deep budding of *M* (cf. Fig. 2, ***B***); ***B***, later stage showing group of small cells (*e*) derived from *M*; ***C***, still later stage, nearly transverse, showing the mesoblast-bands (*m*, *m*) and the group of small cells (*e*) below; ***D***, budding of the posterior macromere, *D*; ***E***, recession of the entoblast-nuclei; ***F***, first appearance of the pigment in the small cells.

their nuclei. The first of them to be formed are budded forth at the surface near the lower pole at a time when the "primary mesoblasts" have budded three or four times (Fig. 3, *D*). Those produced later do not reach the surface, the macromere-nuclei receding from the surface and leaving below them (towards the surface) a closely packed mass or plug of small cells (Fig. 3, *E*), the more anterior of which have been derived from the macromeres, and, therefore, are unquestionably of entoblastic origin,[1] while the more posterior have been derived from the "primary mesoblasts." This plug is bordered in front and at the sides by the ectoblast-cells of the lips of the blastopore, which has now become much diminished in size, while posteriorly it abuts superficially against the ectoblast-cells of the somatic plate (derivatives of "d^2" or "X," the first somatoblast) and at a deeper level against the primary mesoblasts (Fig. 3, *E*). In the cells of this plug are now developed coarse granules of black pigment (Fig. 3, *F*), by means of which they are so unmistakably marked that their later history may be followed step by step with great accuracy. Thus arises the pigment-area at the lower pole of the trochophore larva, described in my first paper on *Nereis*.[2]

In that paper I concluded that the pigment-cells were derived solely from the "primary mesoblasts," having overlooked the fact described above that a part of them, and probably the greater part, are derived from the macromeres (entomeres). I reached the further conclusion that the pigment-cells wandered into the interior and spread out upon the wall of the archenteron to form a part of the splanchnic mesoblast.[3] Renewed studies demonstrate the erroneous nature of this latter conclusion, and prove that *the pigment-cells give rise to the posterior part of the archenteric wall itself.* Both in total preparations and in serial longitudinal sections[4] of the successive stages, every step can be followed of the progressive inwandering of the pigment-cells (Fig. 4) to form the narrower posterior part of the pear-shaped archenteron, while the anterior part is developed from the four macromeres (entomeres) as is proved by the fact, among others, that the fat-drops are found lying in its wall. There is no possibility of mistaking the fact that the pigment-cells actually form the archenteric wall, for their outlines can easily be seen and the pigment-granules are found throughout the whole thickness of the wall (Fig. 4, *B*). The pigment-cells are, therefore, not mesoblastic, but are *entoblast-cells*.

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[1] These cells are obviously comparable to the entoblast-cells of the fourth and fifth quartets (and later entoblast-derivatives) in other annelids. In *Nereis* they show no definite arrangement.

[2] 1892, pp. 412, 417.

[3] *Nereis*, p. 413.

[4] The best results were obtained with strong Flemming's fluid.

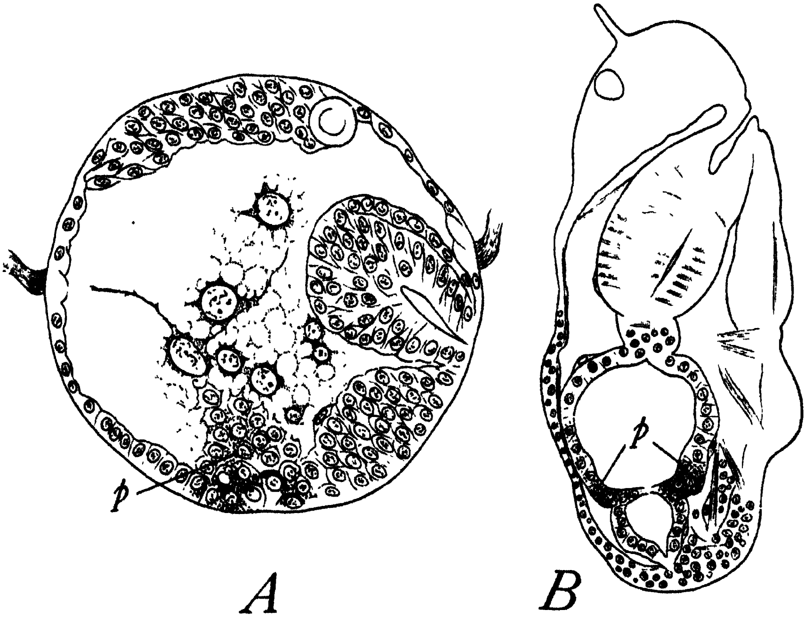

FIG. 4, NEREIS. Sagittal sections of larvæ. ***A***, trochophore (60 hours), showing inwandering of the pigment-cells at the lower pole; stomodæum and neural plate at the right; ***B***, larva of 4½ days, showing the pigment-cells at *p*.

In so far as the pigment-cells are derived from the macromeres (entomeres), this is exactly what we should expect. That cells derived from the "primary mesoblasts" should enter into the formation of the archenteron is however a surprising result; and it is, therefore, highly important to make certain, first whether the pigment-cells are in part identical with or descended from the small cells budded forth from the "primary mesoblasts," and second, whether, if this be the fact, the cells of such origin also wander in to form a part of the entoblast. A careful study of the successive stages in surface views, optical sections, and actual serial sections hardly leaves room for doubt in regard to either point. In the first place, pigment is developed in the small cells that abut directly against the primary mesoblasts (Fig. 3, *F*), and the products of the latter form so considerable a group that it would hardly be possible to overlook their displacement or wandering away did such a process occur before the appearance of the pigment. I can find no evidence of such displacement and hence cannot escape the conclusion that the pigment-cells lying just anterior to the primary mesoblasts have been derived from them. The evidence on the second point, while perhaps not demonstrative, is hardly less convincing. The pigment-cells disappear from the surface *pari passu* with the growth of the archenteron; and when the latter is fully formed (in embryos of five days and upwards) not a trace of pigment can be found at the surface or in any of the cells of the posterior region save those of the archenteron. That the superficial pigment-cells actually pass inwards is proved by the fact that from its first appearance the pigment is densest in two (sometimes three) symmetrical areas which are first seen at the surface and may then be traced progressively inwards in the archenteric wall.[1]

Taken together, these facts leave no doubt, in my opinion, that the pigment-cells are derived in part from the primary mesoblasts, in part from the entomeres, and that the cells from both sources give rise to a portion of the archenteric wall and to no other structure. If this conclusion be correct, it follows that the "primary mesoblasts" are not properly so-called, but are *mesentoblasts*, precisely as Conklin has described in *Crepidula*. Now, there can be no doubt that the single pair of minute cells in *Aricia* and *Spio* represent the group of cells of like origin in

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[1] Cf. 1892, Figs. 79–91, which show this fact, through not as clearly as it appears in my more recent preparations.

Nereis. They must, therefore, be regarded as *vestiges of functional entoblast-cells such as those of Nereis, and morphologically they represent the posterior part of the entoblast-plate*[1] (Cf. Fig. 1, *B;* Fig. 2, *A*).

The foregoing interpretation is entirely in harmony with Conklin's important discoveries in the gasteropod *Crepidula.* Conklin here definitely showed, for the first time in any animal,[2] that the so-called "primary mesoblasts" give rise to a group of entoblast-cells before dividing to form the mesoblast-bands. But more than this, *Crepidula* represents a step in the series which may be regarded as anterior to the condition found in *Nereis*; for here each mesentoblast divides off two entoblast-cells, the bulk of which taken together is actually greater than that of the mesoblastic material remaining, "less than half the cell (4d) being destined to form mesoblast."[3] The three forms *Crepidula, Nereis, Aricia,* thus form a progressive series in which the entoblastic part of the mesentoblast cell is reduced from more than half the bulk of the cell to an insignificant vestige. It is probable that two intermediate steps besides *Nereis* have been observed by Lillie and Mead respectively. The two cells found by the first named observer, in *Unio,* are somewhat larger than those of *Nereis*;[4] while in *Clymenella* as described by Mead, they are equal in size to the mesoblastic moiety.[5]

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[1] It would be interesting to determine whether the vestigial cells of *Aricia* may not be taken into the archenteric wall and thus still retain their functional significance. I have not thus far been able to determine this point; but Mead's observations on *Amphitrite* seem to show that in this form such is not the case, for the vestigial cells are here formed so far from the surface that they pass into the cleavage-cavity and are carried forwards at the tips of the mesoblast-bands. Mead himself concludes that their position in *Amphitrite* is secondary, being a "reminiscence of a surface division which still persists in many forms" (1897, p. 295) I would suggest that their position in *Amphitrite* may be due to the early inwandering of the "primary mesoblasts." It is not surprising that a vestigial cell of this kind should vary somewhat in position; and it should be recalled that in *Nereis* the later-formed cells lie at some distance below the surface. In *Aricia,* too, the vestigial cells do not always reach the surface.

[2] Compare, however, the somewhat similar earlier accounts of Patten for *Patella* (1896) and Stauffacher for *Cyclas* (1893). See Conklin, p. 71.

[3] *Crepidula,* p. 69.

[4] *Unio,* Fig. 60.

[5] 1897, Fig. 88.

Neither of these observers, it is true, suggests the interpretation given above, Lillie somewhat doubtfully assigning to the superficial cells the same fate as I originally did in *Nereis*, while Mead leaves the matter undetermined. It seems probable, however, that we may look for the same fate for these cells as in *Crepidula* or *Nereis*,[1] indeed I venture to think that Lillie's observations are themselves open to such an interpretation.[2]

These facts, I believe, support the view which has been held by many embryologists from the time of Kowalevsky onwards[3] that the primary mesoblasts, or mesoblastic pole-cells of annelids and mollusks must be regarded as derivatives of the archenteron. In both these groups the primary mesoblasts are derived from the posterior cell of the fourth quartet of "micromeres," the lateral and anterior cells of which are, so far as we know, strictly and always entoblastic. The facts indicate, further, that a progressive process of differentiation in cleavage has been going forward, through which the posterior cell of this quartet has become more and more strictly given over to the formation of mesoblast. The vestigial cells of *Aricia*, *Spio*, *Amphitrite* and *Planorbis* would seem to represent the last traces of such archenteric origin of the teloblasts; and it is possible, indeed probable, that there are cases in which even these traces have disappeared, the posterior cell of the fourth quartet being strictly mesoblastic from the first.[4]

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[1] Conklin has fully considered (*Crepidula*, p. 72) the apparently contradictory case of *Umbrella*, as described by Heymons (1893), where cells exactly corresponding to the "posterior enteroblasts" of *Crepidula* are described as giving rise to mesoblast. Despite Heymon's careful account, I venture to think that the case demands re-investigation in the light of Conklin's work. In a recent account of the mesoblast in *Physa* (1897), Wierzejski finds that small cells ("mesoderm-micromeres") are budded forth not only from the "primary mesoblasts" but also from the larger lateral cells derived from them. All these cells are assumed to be mesoblastic, though their fate was not followed out (1897, p. 391).

[2] *Unio*, Fig. 67.

[3] Cf. Kowalevsky, 1871, p. 30; O. and R. Hertwig, 1881, p. 47. Hatschek, 1888, p. 76; Rabl, 1889, p. 207, and earlier literature there cited.

[4] This point must remain doubtful until renewed investigation shall show whether the superficial budding is ever entirely suppressed; for we cannot safely infer its absence from existing accounts, and I am not convinced that my own statement of their apparent absence in *Polymnia* (*Nereis*, p. 458) may not have rested upon an oversight.

The bearing of this conclusion on the possible relation between the teloblastic and enterocœlic modes of mesoblast-formation is obvious. This question will, however, appear in a clearer light after a consideration of the polyclade cell-lineage in relation to the foregoing results.

II.

THE MICROMERE-QUARTETS IN ANNELIDS, MOLLUSKS AND POLYCLADES.

The marvelously close resemblance in cell-lineage between the annelids, gasteropods and lamellibranchs which recent research, more especially within the last five years, has brought to light, leaves no doubt not only that the general forms of cleavage in these groups are reducible to a common type, but also that a considerable number of more or less definite cell-homologies can be established between them, even in the early cleavage-stages. The attempt to extend the comparison beyond the limits of these groups has, however, thus far encountered a very serious stumbling-block in the cell-lineage of the polyclades. If we accept Lang's view, which is supported by a large amount of evidence, that the platodes are not very far removed from the ancestral prototype of annelids and mollusks, we should expect to find in the polyclade a mode of cleavage to which that of the higher forms can in its main features be reduced. In point of fact, however, this seems to be the case only in the *form* of cleavage and not, so to speak, in its *substance*; for, although the general type of cleavage and the arrangement of the blastomeres in the polyclade shows an extraordinary resemblance to that of the annelid or gasteropod, the cells seem not to have the same morphological value. I have elsewhere sufficiently indicated the nature of this difficulty,[1] which has also been remarked by a number of other writers; but for the sake of clearness I will again direct attention to its leading features.

[1] *Nereis*, p. 441; The Cell, pp. 314, 315.

In the typical development[1] of all the forms in question—polyclades, annelids, gasteropods, lamellibranchs—the egg first divides into four quadrants. From these at least three, and sometimes four or five regular quartets of cells—usually smaller, and hence designated as "micromeres"—are successively produced by more or less unequal and oblique cleavages toward the upper pole (diagram, Fig. 5). These quartets are displaced according to a definite law, the first being rotated, as it were, towards the right (clockwise), the second towards the left (anti-clockwise), the third to the right, and so on in regular alternation.[2] The secondary divisions of these micromeres also

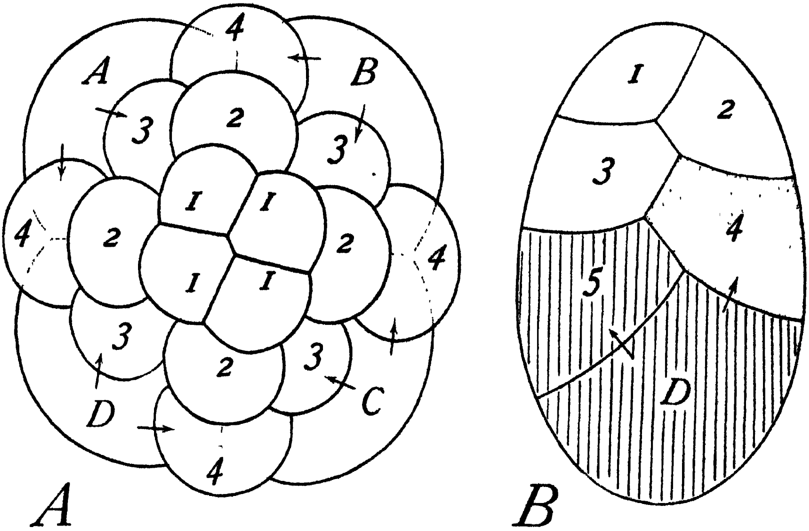

Fig. 5. Diagram showing the typical arrangement of the micromere-quartets in polyclades, annelids and mollusks (their secondary divisions being omitted). ***A***, from the upper pole. ***B***, diagram of the typical history of the posterior quadrant of an annelid or gasteropod embryo; ectoblast is derived from the unshaded cells (1, 2, 3), the mesoblast-bands from the dotted cell (4), ectoblast from the lined cells (5, ***D***).

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[1] There are some well-determined exceptions to this mode of cleavage, and at least one of these—the case of *Polychœrus*, as described by Gardiner, 1895—is apparently irreducible to it.

[2] The reversal of the direction of displacement in the sinistral gasteropods, discovered by Crampton, is an exception which emphasizes the rule.

show a remarkable similarity, in all the forms, up to a certain point. In morphological value, however, the micromere-quartets of the polyclade appear to differ radically from those of the annelid-mollusk type. In the former the first quartet is described as giving rise to the entire ectoblast, while the second and third quartets are mesoblastic.[1] In the latter, on the other hand, these same three quartets give rise to ectoblast, while, as stated above, the main mass of the mesoblast is derived from a single cell (the posterior) of a fourth quartet of which the other three cells form entoblast (Fig. 5, *B*). If a fifth quartet is formed it is invariably entoblastic (Fig. 2, *A*).

At the time attention was first called to these differences it seemed hopeless to reconcile them. Later researches showed, however, that the discrepancy was not so great as it seemed. Lillie first discovered in 1895 that in the lamellibranch *Unio* one cell (the left) of the second quartet give rise to mesoblastic elements (the "larval mesenchyme")[2] and more recently Conklin has found a similar derivation of mesoblast-cells from three cells (right, left and anterior) of this quartet in the gasteropod *Crepidula*.[3]

It is clear that these interesting discoveries partially bridge the gap between the polyclade and the other forms; though how great it still remains may be judged from the fact that Conklin still regarded the differences as "very great, perhaps irreconcilable,"[4] while Mead, in a still more recent work on the cell-lineage of annelids, is forced into a position of skepticism regarding Lang's whole account of the origin of mesoblast in the polyclade.[5]

For these and other reasons a re-examination of the early development of polyclades has become in the highest degree desirable. After a search extending through several years, I have at length succeeded in finding a form very favorable for this purpose—a species of *Leptoplana*[6] having eggs that are large and transparent, are easily procurable in large numbers, and develop so slowly that the successive stages may be very accurately followed in life, while every point may be repeatedly verified in a large number of specimens. The results of a study of these eggs not only help still further to set aside the apparent contradiction between the polyclade and the annelid-mollusk type, but, when taken in connection with the foregoing observations on annelids and gasteropods, also raise some highly interesting questions regarding the relation of cell-lineage to ancestral reminiscence.

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[1] Lang, 1884.

[2] *Unio*, p. 24.

[3] *Crepidula*, p. 150.

[4] *Crepidula*, p. 196.

[5] 1897, p. 289.

[6] An undetermined species found in great profusion at Port Townsend, Washington, on Puget Sound.

I shall not here describe the cleavage of *Leptoplana* in detail, but will only indicate its leading features. Up to the thirty-two-cell stage, and for some distance beyond, the cleavage is a most beautiful example of the symmetrical spiral type, agreeing very exactly with *Discocœlis* as described by Lang, excepting in the fact that in the four-cell stage the cross-furrow is inconstant and often wanting. The first three quartets of micromeres are formed exactly as in an annelid, and have the same position and relative size as in *Discocœlis* (Fig. 5, *A*), while the four large cells remaining give rise to the archenteron. Regarding the morphological value of these three quartets, however, my results differ very considerably from Lang's and are such as to bring the polyclade cell-lineage into direct relation with that of the annelid, gasteropod and lamellibranch. As in these groups *all three of the quartets give rise to ectoblast*, the first and third apparently to ectoblast alone, though I am not certain that the third quartet may not give rise also to a small modicum of mesoblast-cells. The principal interest centers in the second quartet, from which, as Hallez, Götte and Lang have shown, the principal mass of the mesoblast is formed. What these observers have failed to observe is the fact that each cell of this quartet gives rise to several ectoblast-cells—at least three, and probably four—before sinking into the interior to form mesoblast. These divisions are of constant form, as follows: During the fifth cleavage each cell divides unequally towards the left as viewed from the side (*i. e.*, clockwise, as seen from above) to form an ectoblast-cell ("2^1") that abuts against a

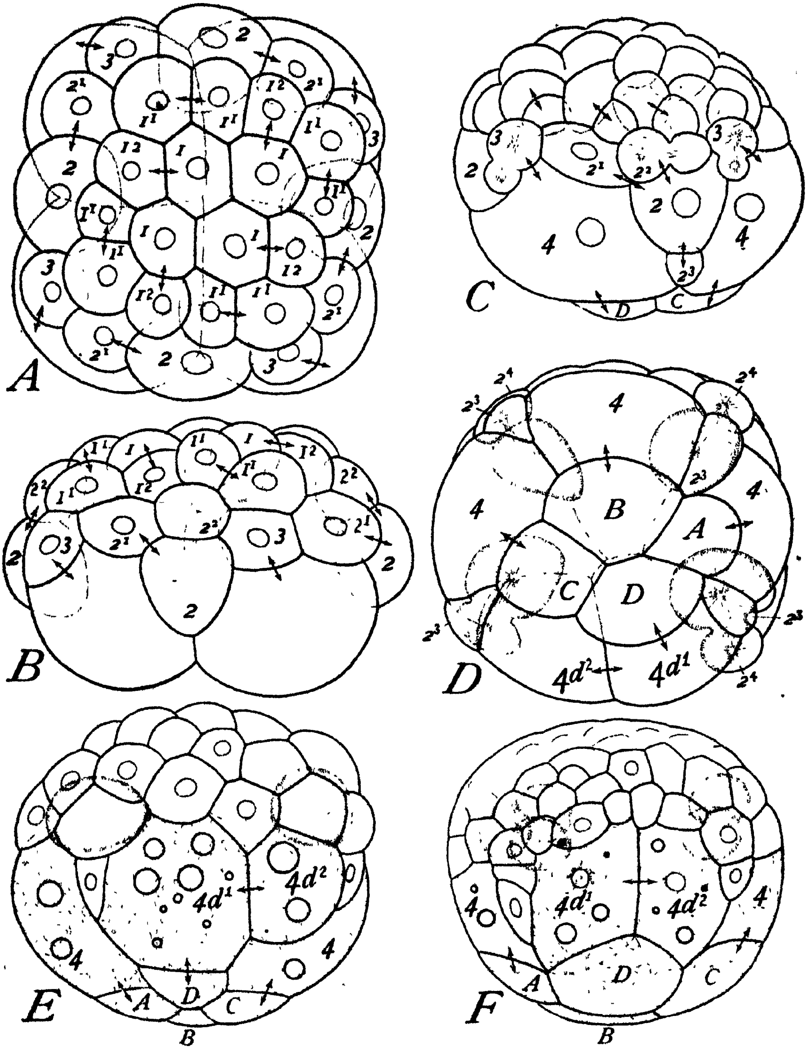

FIG. 6, LEPTOPLANA. (Camera drawings from the transparent living embryos.) **A**, 32-cell stage, from the upper pole; **B**, 36-cell stage, from the side, showing second division of 2; **C**, side view, approximately 60 cells, showing the third ectoblast cell (2^3) derived from 2, the fourth quartet (4) and the basal entoblasts (*D*, *C*). **D**, delamination of mesoblast in the fourth division of 2 (shaded), from the lower pole, showing the basal quartet of entomeres (*A–D*, and the two somewhat unequal cells ($4d^1$, $4d^2$) formed by the vertical division of the posterior cell of the fourth quartet. **E**, posterior view of ensuing stage, showing the two posterior mesoblast cells (shaded) lying in the interior, and a marked inequality between ($4d^1$ and $4d^2$). **F**, later stage; multiplication of the meso-blast-cells (shaded) equality of $4d^1$ and $4d^2$, as in *Discocœlis*.

cell of the third quartet formed about the same time (Fig. 6, *A*).[1] The second division is nearly or quite horizontal, separating a second ectoblast-cell ("2^2") directly above the original or stem-cell (Fig. 6, *B*). The third ectoblast cell ("2^3"), which is very small, is budded forth at the lower tip in the angle between the macromeres (Fig. 6, *C*, *D*). The three cells thus formed (2^1, 2^2, 2^3, Fig. 6) enter, as I believe, into the general ectoblast. At the fourth division the stem-cell divides unequally in a direction parallel to the surface, a large inner cell being delaminated off from a smaller superficial cell (2^4, Fig. 6, *D*). *The inner cell is forced into the angle between the two adjoining "macromeres," and forms one quadrant of the mesoblast; the outer cell flattens out at the surface and is, I believe, an ectoblast-cell,* though I am not entirely sure that it may not ultimately migrate into the interior to form mesoblast. The four primary mesoblast-cells thus formed rapidly multiply to. form four groups of rounded granular cells (Fig. 6, *F*) which may easily be seen for a long time through the transparent ectoblast and from which the greater part, if not all, of the adult mesoblast is derived.

It is clear from these facts that the cells of the second quartet in the polyclade (*i. e.*, in *Leptoplana*) are not purely mesoblastic, but are *mesectoblasts.* It seems equally clear that the formation of "larval mesenchyme" from certain cells of the second quartet in *Unio* and *Crepidula* must be regarded as an ancestral reminiscence or survival of the process that occurs in all four of the cells in the polyclade, and it is an interesting question whether such a survival may not also occur in the embryos of annelids. A careful re-examination of *Nereis* with respect to this point has thus far yielded a negative result. In *Aricia*, on the other hand, it is probable that two mesoblast-cells arise from either the second or third quartet, though the material at my command has not enabled me to reach a decisive result. At the stage shown in Figs. 1, *C*, and 2, *A*, two large and very conspicuous rounded cells are found lying, one on either side, in the cleavage-cavity between the lateral ectoblast and the mesoblast-band (*y*, *y*, Fig.

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[1] Lang figures this division—Pl. 35, Fig. 5.

7) and slightly anterior to the latter. Sections show that these cells are budding forth smaller cells into the cleavage-cavity. I am nearly certain that these cells are not derived from the entoblast; and their position is such that an origin from the primary mesoblasts is improbable. They are often closely wedged in between the overlying ectoblast-cells, and all the appearances indicate that they have been derived from the latter. From their position I believe it probable that these cells have been derived from the two lateral cells of either the third or the second quartet—*i. e.*, from derivation of c^3 and d^3, or of c^2 and a^2 (*Cf.* Fig. 2, *A*)—and that they accordingly are comparable to the "larval mesenchyme" or "secondary mesoblast" (*i. e.*, the ecto-mesoblast) of *Unio* and *Crepidula*. Future investigation must determine whether this surmise be correct, and what is the ultimate fate of these cells, but the facts give, I think, good reason

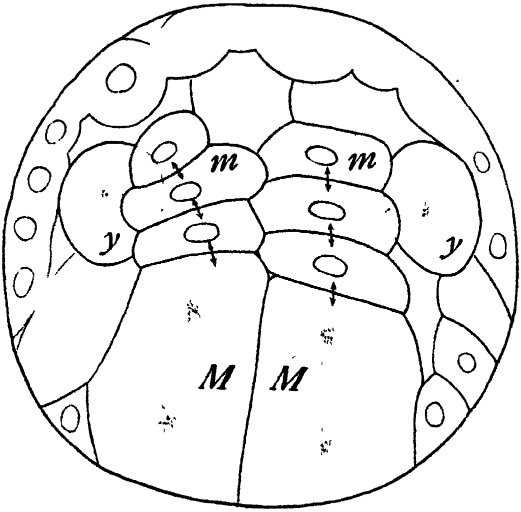

FIG. 7, ARICIA. Frontal optical section[1] of early embryo of *Aricia*, showing the parallel mesoblast-bands (*m*, *m*) extending upwards from the primary mesoblasts, *M*, *M*, behind the entoblast plate (cf. Figs. 1, **C** and 2, **A**, which show the same individual in different positions). At the sides of, and slightly anterior to, the mesoblast-bands are the two mesoblast-cells (*y*, *y*) of probable ectoblastic origin.

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[1] Confirmed by actual sections.

to expect that the annelids will ultimately be shown to agree with the mollusks in showing reminiscences of the ancestral mode of development in the double origin of the mesoblast.

Returning now to the mollusks, Wierzejski, in a recent preliminary paper (1897) states very explicitly that in *Physa* a part of the mesoblast is derived from two cells of the *third* quartet.[1] This result, if well founded, gives good reason to suspect that the third quartet may give rise to mesoblast in some of the polyclades, as Lang has maintained for *Discocœlis.* In *Leptoplana* I have sought carefully for evidence of such a process; but thus far without success. This negative result is, however, inconclusive owing to the difficulty of tracing the later history of the individual cells. The first division of the third quartet is vertical to the surface (Fig. 6, *C*) and in later stages I have thus far found no evidence that a delamination of mesoblast occurs. Soon after the delamination of mesoblast in the second quartet, all of the ectoblast-cells forming the lips of the blastopore become much flattened (Fig. 6, *F*), while the ectoblast-cap rapidly extends downward, the blastopore finally closing at or near the lower pole. In these stages the outlines of the thin ecoblast-cells are very difficult to see, either in life or in preparations, owing to the confusion produced by the underlying deutoplasm-spheres, now much increased in size, on which they are moulded. The mesoblast now forms four groups of rounded granular cells conspicuously seen through the transparent outer cells. A study of the successive stages proves that the greater number of these are derivatives of the second quartet; but the possibility remains that some additions may have been made from the third quartet.

From the foregoing account it appears that the "mesoblast" of the polyclade is derived from the ectoblast; and it may, I think, be taken as a fair working hypothesis that this "mesoblast" is represented in the mollusks, and probably also in some annelids by cells ("larval mesenchyme," etc.) derived from the second quartet (*Unio, Crepidula, Aricia* (?)) or perhaps in some cases from the third quartet (*Physa*, *Aricia* (?)).[1] Assuming this to be the case, what shall we say of the mesoblast-bands, which are in annelids and mollusks derived from the fourth quartet and which, as we have seen reason to conclude (p. 12), are probably to be regarded as derivatives of the primitive archenteron? The development of the polyclade suggests an answer to this question which is in harmony with the facts discussed in the first part of this paper. As earlier observers have shown, the fourth division of the "macromeres" in the polyclade is unequal, giving rise to four smaller cells *at the lower pole* of the embryo (*A–D*, Fig. 6, *C–E*), and to four much larger cells lying above them. From these eight cells, which are heavily laden with deutoplasm and differ entirely in appearance from the ectomeres and mesomeres, the archenteron is formed. With this *Leptoplana* exactly agrees, and I can find no evidence that mesoblast-cells are formed from any of these eight cells. If now we judge solely by relative position without respect to size, the four larger cells or "macromeres" (4–4) correspond exactly with the fourth quartet of annelids and mollusks—in fact, they are relatively not very much larger than in some of the mollusks (*e. g.*, *Planorbis*, *t.* Rabl, 1880). Lang discovered the remarkable fact that in *Discocœlis*, as in so many of the latter animals, the posterior cell of these four divides long before the others; and further, that this division is equal, giving rise to two symmetrically placed cells at the posterior end of the embryo, while the ensuing divisions of the other three cells of the quartet are unequal and irregular.[2] Mead[3] has pointed out the very remarkable resemblance of these two cells in *Discocœlis* to the "primary mesoblasts" of annelids and gasteropods and even goes so far as to suggest that they may give rise to mesoblast-bands in the polyclade. My observations on *Leptoplana* lend no support to this suggestion, agreeing nearly with those of Lang on *Discocœlis* save in one noteworthy respect, namely, that the division of the posterior "macromere" is variable, only rarely dividing equally (Fig. 6, *F*) and as a rule dividing unequally, giving rise to a smaller cell ($4d^2$, Fig. 6, *E*) that is typically formed obliquely towards the right as seen from the side (*i. e.*, in a leiotropic or anti-clockwise spiral.[1] From this it appears that the form of cleavage in the fourth quartet of *Discocælis*, which agrees so exactly with that of the annelids and mollusks, appears as only an occasional variation in *Leptoplana*, though even here the posterior "macromere" is always the first to divide.

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[1] Confirmed by Holmes in the case of *Planorbis* since the above was written. See *Science*, VI, No. 154.

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[1] Edouard Meyer (1890, p. 299) has definitely compared the "parenchyma" (mesoblast) of the Turbellaria with the "larval mesenchyme" of the annelids, which he believes to have a different origin from the mesoblast-bands.

[2] Cf. Lang, 1884, Figs. 17–20.

[3] 1897, p. 289.

As regards the fate of these cells, the inequality of $4d^1$ and $4d^2$ (often very marked) is itself indirect evidence that they do not give rise to symmetrical mesoblast-bands as in the higher types and I find no evidence that either of them gives rise to mesoblast-cells. Both seem to have the same fate as the other entoblast-cells, with which they exactly agree in deutoplasmic structure, and enter into the formation of the archenteron as Lang has shown in the case of *Discocælis*. Can we nevertheless regard them as homologous to, or rather as the prototypes of, the primary mesentoblasts of the annelids and mollusks? When we reflect on the facts, reviewed in the first part of this paper, we may hesitate to answer this question in the negative. For we have seen reason for the conclusion that the primary mesoblasts of annelids and gasteropods have arisen historically, as they arise ontogenetically, *from the posterior part of the archenteron*; and we have traced the entoblastic elements of the posterior cell of the fourth quartet from a minute and apparently functionless vestige (*Aricia*) back to a group of large and important cells (*Crepidula*). I think we should consider the possibility, if only as a working hypothesis, that in ancestral types the entoblastic elements of the posterior cell of the fourth quartet may have preponderated as greatly over the mesoblastic as the latter now preponderates over the entoblastic in *Aricia*; and that the beginning of the series may have been such a mode of development as still occurs in the polyclade where the entire quartet is entoblastic. Thus we are brought anew to the view which has been advocated by a number of morphologists, prominent among them Edouard Meyer,[1] that the mesoblast-bands (ento-mesoblast) of the higher forms may have been of different origin phylogenetically from the "larval mesenchyme"[2]

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[1] Typically—*i. e.*, in probably ninety per cent. of the cases observed, the division is markedly unequal—often much more so than in Fig. 5, *E*. In a few cases the direction of division is reversed, the smaller cell, $4d^2$ being found towards the left (dexiotropic spiral). Sometimes the division is equal and vertical as in *Discocœlis*; more rarely it is horizontal and either equal or unequal. I believe all these variations occur in normal embryos. A considerable time after the formation of $4d^2$ the other macromeres begin to divide unequally and irregularly, and all the macromeres ultimately break up into smaller rounded cells, heavily laden with deutoplasm.

More specifically I would suggest that in the ancestral type the fourth quartet was strictly entoblastic; that at a later period in the phylogeny the trunk-mesoblast (mesoblast-bands of higher types) took its origin from the posterior part of the archenteron, perhaps in connection with the development of a new body-region from the posterior part of the ancestral body; and that as the cleavage became progressively specialized (*i. e.*, assumed more of what Conklin has termed a "determinate type") the seat of this mesoblast-formation became more and more definitely localized in the posterior member of the fourth quartet. The symmetrical division of this cell in the polyclade might accordingly be regarded as the prototype of that which occurs in the annelid or mollusk, though the resulting cells have in the latter forms acquired a different morphological significance. In other words the old building-pattern, still persisting more or less definitely in the polyclade, has been adapted to a new use[3] precisely as in the evolution of adult structures.

I would distinctly repeat that these suggestions are offered only as a speculative working hypothesis; yet, despite their hypothetical character, it seems to me that they may give a new point of attack upon some of the puzzling phylogenetic problems with which the study of cell-lineage has to grapple.

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[1] 1890, p. 299.

[2] † Cf. Conklin, p. 151.

[3] "Imagine that in any species a new organ is added, or rather, that a diffuse series of structures gains great importance and compactness in the course of evolution. Then this new structure *may be* represented in ontogeny by a cell. But the form of cleavage is already defined. * * * The manufacture of a new cell being an impossibility, an old cell must be modified to represent the new organ." (Lillie, 1895, p. 37.)

III.

ON CELL-LINEAGE AND ANCESTRAL REMINISCENCE.[1]

The phenomena shown in the history of the micromere-quartets in platodes, annelids and mollusks are, I think, of general interest in two directions.

In the first place they render it highly probable, if they do not actually demonstrate, that development may exhibit ancestral reminiscence as clearly in the cleavage of the ovum as in the later formation of tissues and organs. That the rudimentary entoblasts of *Aricia*, *Spio*, or *Amphitrite* are such ancestral reminiscences seems almost as clear as that the yolk-sac of the mammalian embryo or the primitive streak of a bird-embryo are such; and the same may be said of the formation of mesenchyme-cells from the second quartet in *Unio* or *Crepidula* These facts, among many others, may well give us hope that, when the comparative study of cell-lineage has been carried further, the study of the cleavage-stages may prove as valuable a means for the investigation of homologies and of animal relationships as that of the embryonic and larval stages. The results of experimental embryology have no doubt seemed adverse to such a conclusion, by showing how easily the cleavage-stages may be altered by changes in the conditions of development. But I cannot see that the embryonic and larval stages are in much better case. Certainly the modification of cleavage-forms which Driesch has effected in the echinoderm egg by pressure, temperature and the like, are hardly greater than those which Herbst has brought to pass in the gastrular and larval stages of the same eggs through modification of the chemical environment. It is true that nearly related forms—for example the gasteropods and the cephalopods—may differ very widely in the form of cleavage; but so they may in the embryonic and larval stages, and it may fairly be questioned whether "secondary modification" or "cœnogenetic change" has gone further in one case than in the other.

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[1] The term "ancestral reminiscence" is here used to denote any feature of development, the meaning of which is only apparent in the light of earlier historical conditions, whether of the adult or of the embryo.

Recent advances in the study of cell-lineage have, it is true, raised some new apparent difficulties in the attempt to establish precise cell-homologies, even between nearly related forms[1] though I suspect that some of these will be found less serious than they now appear. Against these difficulties, however, may fairly be placed an increasing body of affirmative evidence,[2] and on this side may be ranged the observations recorded in the present paper. We should, moreover, remember that just as the homologies of adult parts may be complete or incomplete in various degrees (as Gegenbaur long since urged), so cell-homologies may be more or less definite. Furthermore, just as we cannot always find exact equivalents, in related forms, of the several sub-divisions of homologous nerves or blood-vessels or sense-organs, so we need not expect to find exact homologues for all the individual cells throughout ontogeny. The wonder is, indeed, that so many definite cell-homologies have been established. I believe the facts now known demonstrate the inadequacy of Hertwig's too simple conclusion that the definite values of the blastomeres, and hence of the cell-homologies based upon them, are merely an incidental result of the continuity of development,[3] and that they do not leave without support the plea made five years ago in my paper on *Nereis*, for the study of cell-lineage as a guide to relationship.[4]

In the second place, these facts seem on the whole to emphasize the importance of cell-formation in development. The inadequacy of the cell-theory as applied to development has been very ably urged, especially by Whitman and by Adam Sedgwick; and their conclusions, fortified by the epoch-making discoveries of Roux, Driesch and others on the development of isolated blastomeres, are of an importance that we are only beginning fully to realize. But the time has not yet come for a just estimate of the cell-theory in this aspect; and it may well be questioned whether in the reaction against the cell-mosaic theory, as originated by Schwann, and developed with so much

[1] Cf. Mead, 1897, and Child, 1897.

[2] Cf. Conklin, 1897.

[3] Cf. the very effective criticism of Conklin, 1897, p. 191.

[4] 1892, pp. 367, 455.

ingenuity by Roux and Weismann, the pendulum of opinion may not have swung too far towards the opposite extreme. The persistence in cleavage of vestigial cells (such as the rudimentary enteroblasts of *Aricia*), or of vestigial processes in the formation of the germ-layers (as in the origin of the "mesenchyme" in *Unio* or *Crepidula*) adds to the evidence that the number and character of the cell-divisions stand in some direct and important relation to the differentiation-process; and it would be difficult to explain such ancestral reminiscence in cell-lineage under any view which does not recognize in cell-outlines the definite boundaries of differentiation-areas in the developing embryo.[1] The history of the posterior cell of the fourth quartet in annelids and gasteropods gives a clue to the process through which teloblasts and other determinate protoblasts have arisen by progressive specialization; and I think it lends support to the distinction drawn by Conklin[2] between "determinate" and "indeterminate" types of cleavage by showing some of the steps by which the former may have been acquired.

From a physiological standpoint the persistence of rudimentary cells in cleavage is a problem of high interest which merges into the larger problem of ancestral reminiscence in general. When one considers the analogous case of the polar bodies, one is almost tempted to suspect that the formation of the rudimentary enteroblasts may be in some way connected with a definite transformation of the nuclear substance. It is, however, equally possible that the removal of the *cytoplasmic* substance of these cells may be a necessary condition of the differentiation of the mesoblastic material.

ZOÖLOGICAL LABORATORY OF COLUMBIA UNIVERSITY,
December 4, 1897.

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[1] Cf. Wilson, 1893, p. 14.

[2] 1897, p. 190.

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[ANNALS N. Y. ACAD. SCI., XI., pp. 1–27.]

[ANNALS N. Y. A. S., XI., NO. 2, pp. 29 to 38, March 30, 1898.]

AN "X-RAY DETECTOR," FOR RESEARCH PURPOSES.

C. C. TROWBRIDGE.

(Read November 2, 1896.)

THE "X-ray Detector" is an instrument which has been designed and constructed for the study of fluorescence caused by Röntgen rays. It is a new form of the "fluoroscope," that apparatus which has been so generally used for the observation of the shadow images cast by these rays.

In its construction several devices were used to make it particularly suitable for research purposes, and a name has been given it, in order that it might not be confused with the types of the instrument previously constructed.

A description of the "X-ray Detector" will be more clearly understood, if a brief reference is first made to the original forms of the "fluoroscope."

Shortly after the discovery of the X-rays, several investigators independently perfected the method of using the fluorescent screen, employed by Professor Röntgen in his first experiments with these rays, and devised an instrument for the study of the shadow pictures of this recently discovered form of energy.

Professor E. Salvioni, of Perugia University, Italy, and Professor William F. Magie, of Princeton College, in this country, appear to have been the first to construct and use such apparatus. Both were apparently working on similar lines of research and developed the same idea independently of each other.

In a paper read before the Perugia Medico-Chirurgical Society on February 5, 1896, Professor Salvioni gave an account of an instrument, devised by himself, for the observation of X-ray shadow effects, in which he made use of the fluorescent screen.

A short article by Professor Magie, describing a similar contrivance, appeared in *The Medical News*, of February 15th. It ran thus: "A sheet of black paper coated with platinum-bari-cyanide, is placed with the coated side inward across the end of a tube or box, into which the observer looks, and which is so fitted to the face or shielded by cloths that the phosphorescent substance and the eyes are protected from all extraneous light." "If the tube be then directed towards the Röntgen rays, the phosphorescent paper in the tube glows and the shadows of objects interposed between it and the Crookes tube appear upon it." Professor Magie subsequently suggested that the name of "skiascope" (an instrument to show shadows) be given to the apparatus.

About March 20th, or a little over a month after the publication of Professor Magie's article in *The Medical News*, the Edison fluoroscope appeared. It was essentially the same instrument as that described in *The Medical News*, except, that the fluorescent substance, used by Mr. Edison to coat the screen, was tungstate of calcium, which had been adopted because it was believed by him to have greater fluorescent properties than the barium platino-cyanide, and that it was provided with a binocular eye-protector, made to fit close to the face and shut out all light from entering the apparatus at that end; thus allowing both eyes to be used to observe the screen. The instrument was furthermore made in a convenient form, and one which was considered desirable for commercial uses. The "fluoroscope" or "skiascope" is very valuable for the observation of Röntgen ray shadows, and has already been of considerable assistance in a number of surgical operations, but it can only be used for approximate tests in scientific research, and is entirely unfitted for certain investigations, for reasons which will be demonstrated below.

Although in the greater number of investigations with Röntgen rays the photographic negative should be used in order to obtain the most satisfactory results, there are a number of important experiments relating to the various phenomena of Crookes tubes which must be conducted by other methods.

From these facts was evident the need of a scientific instrument suitable for studying the phenomena of Röntgen rays, and one that could be perfectly relied upon. An apparatus designed for such purposes was constructed by the writer in May, 1896, under the supervision of Professor Rood, of Columbia University, who suggested some of its important devices. Several forms of the instrument were exhibited before the New York Academy of Sciences at the meeting of November 2, 1896.

The "X-ray Detector" is shown in outline in figures 8 and 9. In these cuts the main casing of the instrument is represented by *A*. It is made of thin wood, that is perfectly impervious to ordinary light, and is 30 centimeters in length. The ends of the casing, *A*, are rectangular, but differ somewhat in dimensions; at the extreme end, next to *B*, the outside meas-

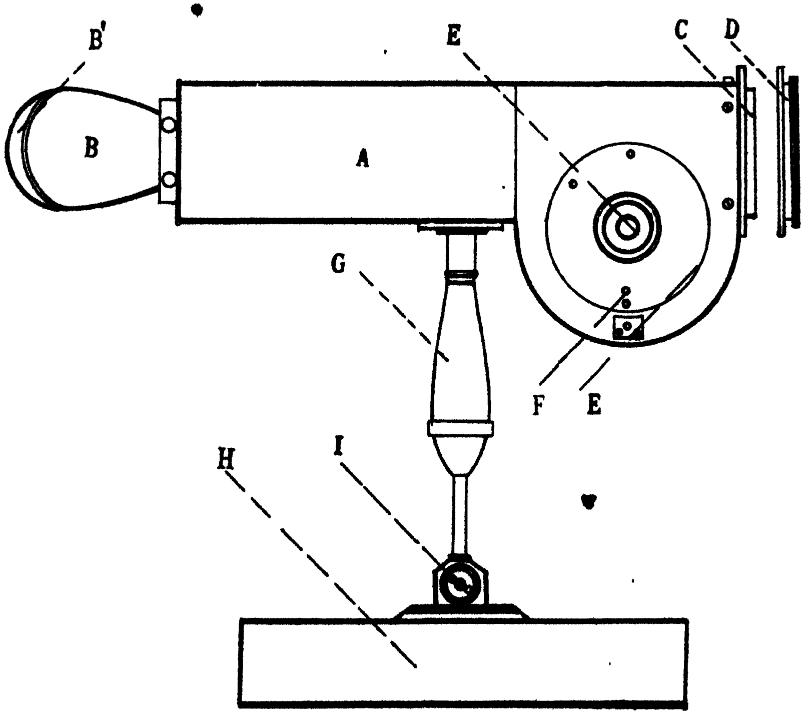

FIG. 8. Side view of the "X-Ray Detector."

urements are 11 centimeters in width by 7.5 centimeters in depth, while at the opposite end, at *C*, the casing is square, being 7.5 x 7.5 centimeters.

Just back of the end *C*, the lower portion of the casing is enlarged by a half-cylinder or half-drum extension of 6 cms. radius, which was added so as to conform the shape of the casing to certain devices which comprise a part of the interior construction of the apparatus. The entire inside of the instrument, including all the brass parts, is painted a dead black.

B, in figs. 8 and 9, is a binocular eye-protector of patent leather, which is shaped to fit above the eyes, and has a black velvet cushion on the edge, marked *B'*. This cushion is added so as to prevent, as far as possible, all light from entering the instrument from around the edge of the eye-protector. It is made soft and elastic, in order that it may readily be made to follow the contour and set close to the face of the person using the instrument.

At the opposite end from *B* is a brass screen holder, *C*, which measures 7.5 x 7.5 centimeters, and is constructed to fit exactly into the end of the casing *A*. In this screen holder there is a circular aperture 5.5 cms. in diameter, which is encircled by a thin ring of brass that extends .5 cms. outward from the main portion of the screen holder. A screen of black paper is placed over this opening, having on its inner side crystals of barium-platino-cyanide ($BaPtCy_4 + 4Aq$), tungate of calcium ($CaWO_4$), or

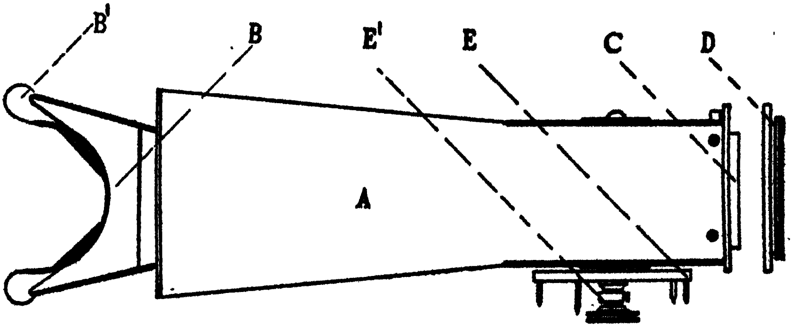

FIG. 9. Top View of the "X-Ray Detector."

some other strongly fluorescent substance. These crystals are uniformly distributed over the area of a circle 5.5 centimeters in diameter.

The black paper screen is held securely in place by a cap, *D*, which is circular in form, and which fastens over the ring on the screen holder, *C*, in such a manner that it is impossible for light to enter the instrument from that portion. The construction of these parts is such, however, that the cap, *D*, can be very easily removed and the screen taken out and another substituted in its place.

A device which is used by the X-ray Detector for purposes which will be presently explained is shown in fig. 10. Its position in the apparatus can be seen in figs. 8 and 9. In these figures *E* is a disk of brass 7.5 cms. in diameter and .15 cms. in thickness, fitted on a small shaft .5 cms. in diameter, that passes through the casing of the instrument from one side to the other, 6 centimeters back of the screen holder *C*, but below a line joining the aperture in *C* and the eye-protector *B* (Fig. 8); so that a view of the screen from the eye end is not crossed by the shaft. On this shaft, but inside the instrument, is fastened a metal shield, as shown by *L*, in fig. 10, which measures approximately 6.0 x 6.0 centimeters, and extends radially outward from the shaft.

Diametrically opposite to the shield *L*, two metal posts support a cross-bar *J*, fig. 10, 6.0 cms. long, and 1.6 cms. in thickness, parallel to the shaft, and such a distance from it that when the shaft is turned to one position, this bar will cross the center of the field of the fluorescent screen.

The entire device can be made to revolve by turning a milled-head *E'*, fig. 10, attached to the brass disk *E*, and is so constructed, that if the shaft be turned to certain positions by means of this milled-head, the view of the screen, as seen from the eye-protector, may be partly or entirely shut off by the metal shield *L*, fig. 10, or it may be bisected by the cross-bar *J*, fig. 10. Thus the view of the fluorescent screen may be changed, in the different positions of the shaft, from a full to a half-moon effect, to perfect occultation, and to the field of a circular screen crossed by a bar.

The exact setting of the shield and cross-bar can be determined in the following manner: Outside of the box on the brass disk *E*, and near its edge several short rods, 6 cms. long, are placed. These are pointed at the ends and project outward from the face of the disk. They are indicated by *F*, figs. 8 and 10. One rod indicates the position of the cross-bar inside,

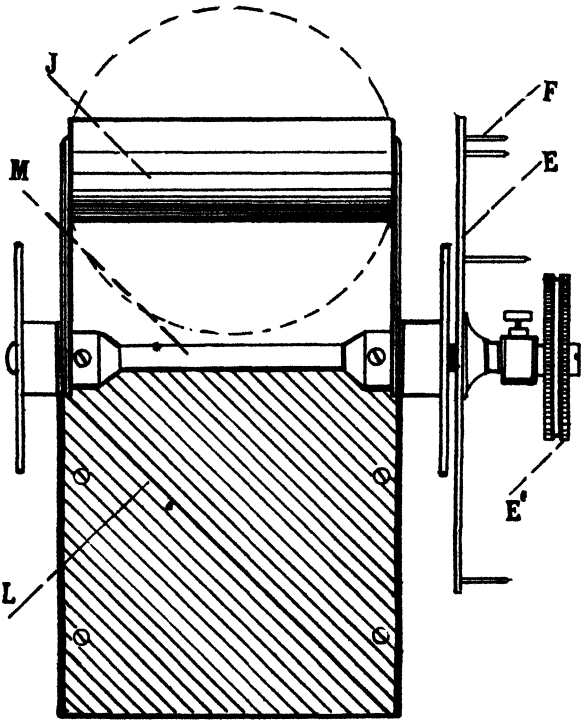

FIG. 10. Revolving device used in the "X-Ray Detector."

and two rods the position of brass shield. Just beyond the edge of the disk *E*, figs. 8 and 9, and projecting from the casing of the instrument is a rod similar to those on the disk. The pointed rods on the disk *E* are so arranged, that if one of them coincides with the stationary rod on the casing of the apparatus, it shows that the cross-bar inside is bisecting the field of the fluorescent screen. If the two on the disk are in coincidence with the stationary rod, it indicates that the view of the screen inside has been completely shut off. There is also a rod one centimeter long on the disk in that position which corresponds to the half-moon effect referred to in the last paragraph.

The device for changing the view of the screen of the instrument is for the purpose of giving the experimenter a means of determining whether the screen, which is supposed to be under the influence of X-rays, is really fluorescing or not. For, although the screen may appear to be luminous, the effect of vision may be only an optical delusion.

The contrivance shown in fig. 10 is used to test observations as follows: If there seems to be a fluorescence of the screen, the experimenter can attempt to set the cross-bar, J, fig. 10, over the center of the luminous field.

Then, afterwards, the real position of the bar can be determined with absolute certainty by means of the indicating disk on the outside of the instrument. If the luminous effect was caused by light coming from the screen, and the setting of the cross-bar made correctly, a coincidence must be found between a certain one of the rods on the disk and the stationary rod on the casing of the instrument, as previously explained. The relative position of these rods is determined by the sense of touch with the forefinger of the right hand. When the right coincidence is found to exist, the conclusion must be that the screen is fluorescing.

Thus we have a checking device on the observations of the fluorescence, which is perfectly free from any personal equation.

As it is often desirable to work with Röntgen rays completely in the dark, Professor Rood suggested the use of the small pointed rods on the brass indicating disk instead of marks, in order that the investigator might remain in darkness during experiments and determine the position of the revolving checking device (shown in figure 10) by the sense of touch.

The means of eliminating the personal equations just described, is important, because a conscientious observer may be led by the imagination to believe that a fluoroscopic screen is fluorescing when it is really not. There are certain phenomena pertaining to human sight and recognized in physiological optics, giving the effect of a vision of dim grayish light, which occur when the eyes are closed or in the dark. Such effects, together with after-images, might often be a cause of deception when an instrument is used which is unprovided with a means for verifying observations of faint luminosity.

These phenomena are sometimes so vivid that they may readily cause a person to believe that a pale light is coming to the eyes from without, when the effect is really subjective and in the eyes of the individual who is experimenting.

The name "X-ray Detector" was considered suitable for the instrument and was adopted, because the apparatus was designed particularly for the study of the fluorescence which is caused by Röntgen rays, and for the reason that it is possible to determine with it whether a screen of fluorescent material, which is supposed to be under the influence of the X-rays, is actually giving forth a perceptible amount of light, or whether the effect which is apparently observed is due only to an optical delusion.

For most experiments of a scientific nature, a decided contrast between a luminous screen and the dark boundary surrounding it is always desirable. A good contrast is obtained by the employment of a comparatively small screen, such as is used in "X-ray Detector." This is the case for two reasons: In the first place, that portion of a Crookes tube which is the main source of Röntgen rays is generally quite small, seldom being of greater extent than a few square centimeters.

If, therefore, a large screen is placed close to the source of these rays, it will exhibit uneven fluorescence, one part showing intense luminosity while the other portions appear faded out. Such an effect tends to give little contrast between the fluorescing screen and the dark border surrounding it. On the other hand, a small screen is fairly evenly fluoresced, its entire border has equal definition, and all the contrast which is possible is obtained.

Secondly: When a flat surface is observed at a short distance from the eyes (20–30 centimeters), only a small portion of it is distinctly seen at one time. Thus it follows, that a small screen will be more clear than one that is large, because it lies more nearly within the area of distinct vision, and its border has better definition than that of the large screen.

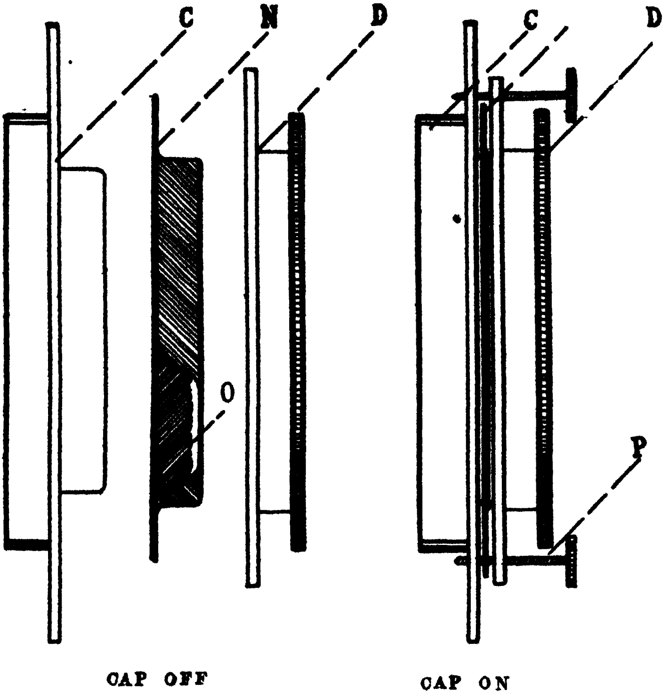

FIG. 11. Device for holding fluorescent screen in place, showing the cap off and the cap on. C—Screen holder. H—Black paper screen. O—Fluorescent crystals. D—Cap. P—Screws for securely fastening the cap.

By the construction of the screen holder of the "X-ray Detector," *C*, fig. 8, so that screens can be easily changed, a means is obtained by which comparative tests and examinations of different fluorescent substances can be made. One method is as follows: If it is desired that two fluorescent materials be compared; screens of these substances are prepared, and then the farthest distance from an active Crookes tube at which each screen appears to be luminous is measured. The ratio of the squares of the two distances will show the relative fluorescent values of the substances, at least from an optical standpoint. In this test, the checking device which is shown in fig. 10 is used to determine the correct distances. The screen holder, screen and screen cover are drawn in detail in fig. 11.

The "X-ray Detector" is provided with a base, *H*, fig. 8, which is an advantage, because it is desirable that experiments should be conducted under steady conditions. This stand has been made very firm, and has a device by which motion in three planes is possible, when observations are required with the "X-ray Detector" in different positions with respect to the source of the Röntgen rays. The instrument is also so constructed that it can be easily freed from the base and held by a handle (*G*, fig. 8) in the hand of the experimenter.

The particular apparatus, described and shown in the accompanying illustrations, was made by J. Grunow, instrument maker, New York, N. Y., from a model constructed by the writer.

[ANNALS N. Y. A. S., XI., NO. 3, pp 39. to 43, March 30, 1898.]

THE USE OF THE FLUOROSCOPIC SCREEN IN CONNECTION WITH RÖNTGEN RAYS.

C. C. TROWBRIDGE.

(Read November 2, 1896.)

IN a previous paper by the writer entitled "An 'X-ray Detector' for Research Purposes," containing a description of an instrument designed and constructed for use in the study of Röntgen rays, a reference was made to those investigators who had improved the methods of using the fluorescent screen in connection with the Röntgen rays. Mention was made of Professor E. Salvioni, of Perugia University, Italy, and Professor William F. Magie, of Princeton College, as being two investigators who, working independently, were the first to construct and describe an instrument which greatly simplified the manner of using the fluorescent screen in experiments with these rays.

Professor Salvioni gave an account of his apparatus in a paper which he read before a meeting of the Perugia Medico-Chirurgical Society on February 5, 1896. A translation of the same appeared in *Nature*, March 5, 1896, page 425 (No. 1375, Vol. 53). The original manuscript having been published in the *Proceedings* of the Academia Medico-chirugica di Perugia of February 6, 1896, Vol. VIII, No. 1–2. The instrument was called a "cryptoscope," and was described in the article as a cardboard tube 8 centimeters high, having at one end a screen of black paper, on which had been spread a layer of calcium sulphide, a substance that is fluorescent under the influence of X-rays. At the other end, where the eye was placed, a lens was fixed, which gave an image of the screen.

The priority of publication in this country of a description of a piece of apparatus similar to that described above, belongs to Professor Magie, who wrote a letter concerning it to *The Med-*

ical News under the date of February 5, 1896, which appeared in the issue of February 15th of that weekly (Vol. LXXIII, No. 7, page 192). The paper was entitled " A Convenient Instrument for Visual Use in Diagnosis with the Röntgen Rays."

Another article, " Application of Röntgen Rays, the Apparatus and its Use," by the same writer, was published in the *American Journal of the Medical Sciences* for March, 1896, Vol. CXI, page 251. In the second paper Professor Magie referred to the instrument which he had devised, and called it the " skiascope," as being a name appropriate to its uses.

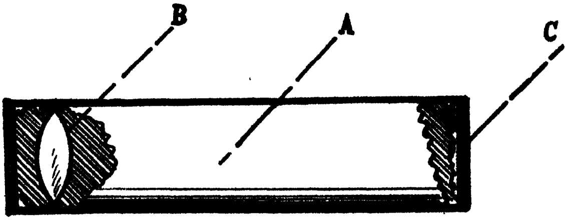

FIG. 12. Cryptoscope devised by Professor Salvioni.

The first two illustrations which accompany this article are intended to show the instruments which have just been described. In fig. 12, the " cryptoscope," which was devised by Professor Salvioni, is shown. The letters which represent the parts in the cut are as follows : *A*, a tube 8 centimeters long, *B*, a lens used to obtain an image of the screen, and *C*, a screen of fluorescent material.

Fig. 13, shows the " skiascope " as first devised by Professor Magie. In the figure, *A* represents a tube about four centimeters in diameter ; and *C*, the fluorescent screen. At *B*, the tube was pressed tight against the face about the eye. *T* is meant to indicate a Crookes tube. The third cut, fig. 14, which shows the Edison fluoroscope, has been drawn for the purpose of comparison. Although this apparatus is quite familiar to many, it is described, and its uses are outlined, because it is the form of " fluoroscope " which has been most generally used since the discovery of Röntgen rays.

The Edison fluoroscope has been used mainly to obtain an actual vision of the silhouette shadows cast by objects which the Röntgen rays do not readily penetrate, such as the bones of the human skeleton and metallic objects. In Figure 14, *A* represents a wooden box about 28 centimeters long, shaped as in the cut, and open at the small end at *B*, where there is a binocular eye-protector of patent leather, which is made to fit closely about the eyes, so as to exclude all light from the sides, but allowing the observer to look into the box. At *C*, in the large end of the box *A*, is a screen of cardboard coated on the inside with a fluorescent substance. The screens were at first made of tungstate of calcium, but now barium platino-cyanide is the material generally used. The apparatus is also provided with a handle. If it is desired that the shadow of the bones of the human hand shall be seen, the instrument is used as follows: The fluoroscope is held to the eyes with the screen end placed before a Crookes tube emitting strong Röntgen rays. The screen immediately becomes luminous, because the fluorescent substance thereon converts the energy falling on it in the form of X-rays, into the rays of ordinary light.

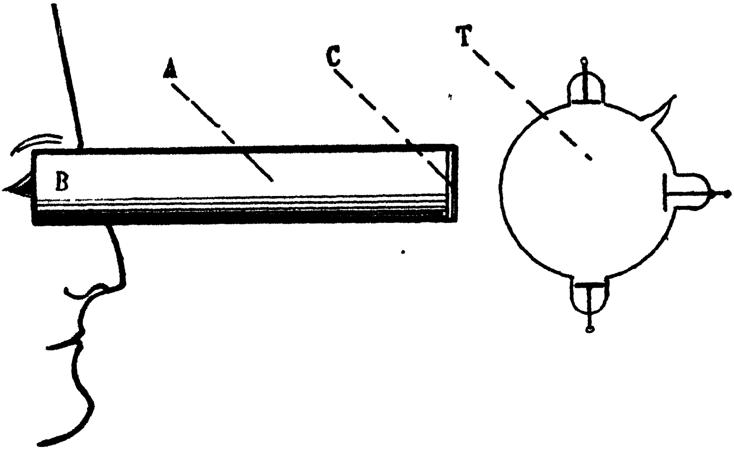

FIG. 13. Skiascope devised by Professor W. F Magie.

The hand is then interposed between the fluoroscope and the source of Röntgen rays; and its shadow appears on the screen, but as the bones absorb the rays to a much greater extent than the flesh, they are projected as dark shadows, while the shadow of the flesh is so faint that it can hardly be seen. Thus, the bones of the hand appear distinctly in outline; the effect being somewhat similar to the silhouettes of ordinary light.

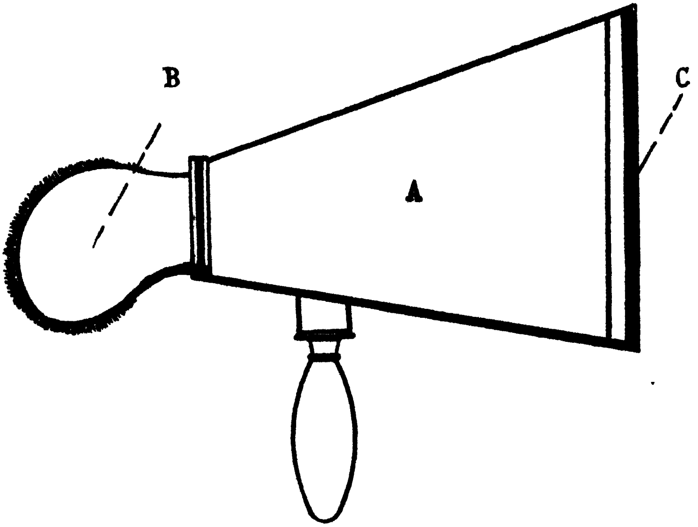

FIG. 14. Edison Fluoroscope.

Most of the appliances for obtaining visual effect of Röntgen rays by the use of the fluorescent screen are based on the discoveries of Professor Röntgen, for it was he who first discovered that fluorescent substances became luminous under the effects of the X-rays. He studied both this phenomenon and the effect of the rays upon the photographic negative in his famous research, and obtained shadows of the bones of the hand by the use of the fluorescent screen, as well as the more permanent shadow-pictures by the photographic process.

The fluorescent effect of certain materials when subjected to the influence of Röntgen rays was, however, partly anticipated by certain observations of Dr. Lenard, of Bonn. This investigator found that, if a small aluminum window was fitted into the end of a Crookes tube opposite to the kathode, and if the tube was excited in the usual manner by means of an induction coil, certain materials would show fluorescence when they were placed within a distance of six centimeters from the aluminum window. Although this effect may not have been due to Röntgen rays—which had not then been discovered—yet the experiment showed that certain phenomena relating to Crookes tubes could be advantageously studied by the use of screens of fluorescent material.

The "X-rays" which were discovered by Professor Röntgen, and which were emitted from an ordinary Crookes tube, were observed to effect fluorescent substances as far distant as two meters. The room in which Professor Röntgen conducted the experiments was darkened, and the Crookes tube which was used was covered with black paper. Then, when the fluorescent substances were brought near to the tube and in the path of the X-rays, the fluorescence mentioned above was observed. It will be seen, therefore, that the appliances which are used now to observe X-ray shadowgraphs and fluorescence are simply improvements of the methods used by Professor Röntgen.

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COLUMBIA UNIVERSITY.

[ANNALS N. Y. A. S., XI., No. 4, pp. 45 to 54, March 30, 1898.]

ON HYPERTROPHIED SCALE-LEAVES IN PINUS PONDEROSA.

FRANCIS E. LLOYD.

(Read January 10, 1898.)

[PLATE I.]

EARLY in 1896 the writer was engaged in the study of pollen development and, in order to supply himself with materials, broke off a number of young staminate shoots from a specimen of *Pinus ponderosa*, the Bull Pine or Yellow Pine of the West. An examination of the same tree in the autumn discovered that the pruning of these large, rapidly growing shoots had resulted in the growth of one to three lateral shoots, a little distance below the break. These lateral shoots which were developed from the axils of scales on the upper portion of the shoot of the previous year were sterile, but differed in a remarkable degree from the normal foliage shoots. In the latter the leaves are borne in groups of threes (fascicles) upon very short branches which spring from the axils of small triangular scales which are to be regarded as reduced leaves. In the shoots induced by pruning, however, these scales have been greatly developed, so much so, indeed, as to have become leaves, both in structure and function, while the fascicles, so called, were in most cases not developed at all. When they were developed, however, there was produced the phenomenon of a twig with foliage leaves of two distinct kinds. The same operation was carried on in the spring of the following year (1897) which resulted similarly. In one case, however, a staminate shoot was produced.

It has been commonly observed, and was pointed out by Masters[1] in 1880, that upon the Juniper, especially upon young specimens, there are found two kinds of leaves. Masters called these two kinds the juvenile and adult forms, and suggested that the former, which are much the longer and sharply pointed, represent an ancestral condition. In this way, also, he compared *Retinospora* to an immature stage of *Thuya* inasmuch as plants of the former genus suddenly assume the foliage characteristics of the latter. It will be seen, however, that these two cases, *Pinus* and *Juniperus* are not quite parallel, for the ordinary foliage or secondary leaves of the former are produced upon the reduced twigs in groups or fascicles, in which the number of leaves is practically constant for a particular species, while this arrangement is not found in the junipers. The structures in *Pinus* which should be compared directly with the leaves of *Juniperus* are the primary leaves, and later the scales which subtend the fascicles. Dimorphism in the leaves of the seedlings of *Pinus* is a constant feature. The cotyledons are followed immediately by the primary leaves, so called by Engelmann,[1] and it is only later that the fascicles are produced. The same writer also drew attention to the fact that these primary leaves, or similar ones, are also found upon sprouts of certain species (*P. inops*, *rigida*, *Canariensis*, etc.), and are frequently upon young shoots of *Larix*. The structure of the cotyledons, primary and secondary leaves were studied comparatively by Daguillon[2] in 1890. He included in his studies five genera, *Abies*, *Picea*, *Pinus*, *Larix*, and *Cedrus*, and showed that the ontogenetic series of leaves from the cotyledons to the adult, present a series of gradations, gradual in *Abies*, but more pronounced in *Pinus*. Of the species of *Pinus*, Daguillon studied four (*P. strobus*, *pinea*, *maritima* and *sylvestris*).

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[1] Nature, XXIII: 267. 1880.

The primordial leaves which are produced in the seedling on the stem above the cotyledons are in all cases elliptic in transverse section, and have two resin ducts in contact with, or very near the lower epidermis. In *P. maritima*, they are very near the lateral angles. The supporting tissues are less strongly developed and the vascular bundle is single. In one species only of those studied is the vascular bundle single in the adult leaf, *P. strobus*, while in the others, the bundles, which are two, are widely separated.

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[1] Engelmann, "Revision of the genus *Pinus*," Trans. St. L. Acad. IV, 1880.

[2] "Recherches sur les fuilles des Coniferes." Rev. Gen. d. Bot. II: 154. 1890.

It appears that the structures of the primary leaves produced upon shoots, already mentioned, has not been studied, but it has been assumed to be the same as that of the true primary (primordial of Daguillon) leaves of the seedling.

There can be no doubt that the bud scales, and the scales which subtend the fascicles of *Pinus* are reduced leaves. In view of this fact it is of peculiar interest that we are able to cause their return to the foliage condition, in that we have clearly a case of atavism. Furthermore, the structure of an hypertrophied scale-leaf, if we are right in regarding this as a case of atavism, ought to furnish some clue as to the phylogeny of the genus. It is assumed in such an argument that leaf characters are to be depended upon as a guide, and of this, I believe, there can be little doubt, for it has been abundantly shown that these characters are quite constant. This is especially true, I believe, as regards the position of the resin ducts concerning which Engelmann wrote that it is "so constant and seems to be so intimately connected with the essential character of the plant, that I venture to adopt it as one of the principal characters for the subdivision of the genus." Let us turn to the consideration of the facts and see whether we may gather any conclusions from them.

The staminate shoots have normally small, scarious scales, in the axils of which in the upper part of the shoot, are produced the staminate cones. If these shoots are cut off, one, two or perhaps three axillary buds on the upper end of last year's shoot will develop. So far I have been able to get no more than three buds to develop. These buds, when developed into shoots, have leaves which are narrowly triangular in outline, broader at the base, and tapering gradually from the base to the apex, and are of various lengths. The longest leaf observed measures 6 cm. From the axils of some of these leaves were developed normal fascicles. The transverse section shows them to be flattened above and ridged along the middle line below.

The margins are finely serrate, as is also a low ridge which runs along the middle line on the upper surface. The surface is markedly glaucous, and stomata are found on the upper surface arranged in ten longitudinal rows and on the lower surface in four rows, one row on each side of the two resin ducts.

A transverse section shows that the epidermal layer, one cell in thickness, is underlaid by a layer of hypoderm, consisting of strengthening cells, which, as a rule, does not exceed one cell in thickness except at the angle of the lower side where an incomplete second layer is found. The resin ducts are two and are in contact with the lower epidermis.

The parenchyma is of cells of the infolded kind which is characteristic of the group.

A fibro-vasal sheath is rather weakly developed enclosing two bundles, which are slightly separated, consist of the usual elements and are surrounded by pitted vessels. The vascular bundles are weaker than in the normal leaves, and are closer together. The stomata are in nine to twelve rows on the upper, and in four rows on the lower surface, and the latter are so disposed as to be one on either side of the two resin ducts.

The normal leaves are about 20 cm. long, and, springing as they do in threes from the fascicles, are in transverse section the shape of a sector of 120°. Such long, slender "needles" require and possess much stiffening tissue which occurs as hypoderm of several cells in thickness. The resin ducts, two in number, are here found deep in the parenchyma, opposite the lateral angles. The endodermic sheath is relatively larger and contains two strongly developed vascular bundles which are more widely separated than in the hypertrophied scales. Without and surrounding the bundles is a mass of tissues composed of pitted vessels. The stomata occur in twelve rows on the upper and in thirteen to fifteen rows on the lower surface.

It will be seen then that the abnormal leaves in question differ in the arrangement of tissues quite markedly from the normal. They approach, in fact, very closely to the early or primordial leaves in the species of *Pinus* described by Daguillon. These latter, however, are in their plan of structure very similar to the type of leaf seen in *Pseudotsuga*, and in many species of *Abies*, and to this extent we would seem to be warranted in saying that the Pines have been derived from a generalized form having a leaf and other characters midway between the firs and spruces. The nearest living representative of such a form is *Pseudotsuga.* As regards the strobile, while pendant and spruce-like in certain characters, especially when young, in its large scales it is fir-like. As regards the leaves, it is decidedly fir-like. As to general habit, it is spruce-like.

There is another value to be attached to this comparison between abnormal leaf and true primary leaf. Their close correspondence in structure supports Celakovsky's view that abnormalities in the Conifers are of very great value as a basis for morphological study.

It has been said earlier in this paper that we have in these abnormal leaves a retrogression to ancestral types. If this be so we should look for a condition in the more immediate ancestral forms of the pines in which the primary leaves are normal, and later, intermediate forms should show a gradual substitution of fasciculated leaves for scattered ones.

Now there have been found in the Jura of eastern Siberia certain forms which were described by Heer[1] under the generic name of *Leptostrobus.* The description was originally based upon the cones only. Further material was afterwards obtained which showed the leaves to be pine-like and apparently fasciculated at the ends of the short twigs. The material was, however, meagre, and nothing further was made out in regard to the arrangement of the leaves.

Later Fontaine found in the Potomac of the Eastern United States forms evidently closely allied to Heer's *Leptostrobus.* These he described[2] under *Leptostrobus*, taking the precaution, however, of extending the original description by the addition of the following remark bearing on the position of leaves "leaves . . . scattered on the larger or principal stems and grouped in bundles on the ends of short twigs." This was a very wise procedure, inasmuch as Heer's material, judging from his plates, does not offer any evidence in regard to the body of the twigs, but only as regards the ends, and even as to this the material is meagre. In all probability more extended search would discover that Heer's *Leptostrobus* possessed the two arrangements of leaves, scattered and fasciculated, since this is true of Fontaine's forms described under this genus.

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[1] Flor. Foss. Arctica, VI : 23.

[2] U. S. Geol. Survey, Monograf XV.

It may be further remarked that with *Leptostrobus* Fontaine found other fossils which referred to a new genus, *Laricopsis*. These in general are larch-like, but like *Leptostrobus*, possess two kinds of leaves—fasciculate and scattered. Fontaine draws attention to the fact that the young shoots of *Larix* occasionally produce the scattered or primarily leaves and compares them to the permanent scattered leaves in *Laricopsis*, the probable ancestral form from which the Larch has been derived. It is reasonably certain, therefore, that in *Leptostrobus* and *Laricopsis* we have closely allied forms which lived together and were the forerunners of the Pines on the one hand and the Larches on the other.

As to the causes which bring about the hypertrophy of the scale-leaves in *Pinus ponderosa* it may be said that the increase in nutrition plays no small part in the matter. Fujii[1] ascribes certain changes produced in the cones of a Japanese *Pinus* after pollarding to over nutrition. Those species of *Pinus*, already noted, which produce sprouts, do so from the stump after the tree has been cut down, and these sprouts have dimorphic leaves. The same result can be produced in *Pinus ponderosa* by cutting off the staminate shoots to which, normally, a large amount of food would pass. This food is diverted by pruning. It is, however, not enough to say this, for there must be some other factors at work. What they are we are not in a position now to say.

SUMMARY.

Abnormal leaves are produced upon shoots induced by pruning the staminate shoots of *Pinus ponderosa* by the hypertrophy of the scales. The latter are thus shown to be reduced leaves. They are to be compared to similar structures found on shoots of certain other species of which *Pinus rigida* is an example. These species are those which readily produce sprouts from the stump. They may further be compared to the scattered leaves occurring occasionally upon *Larix*.

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[1] Fujii, K. Bot. Mag., Tokyo, IX, 275–271. 1895.

The structure of these abnormal leaves is not identical with that of the true primary leaves—those produced on the seedling on the stem immediately above the cotyledons. While not so primitive as these primary leaves they may be compared more properly to the *Pseudotsuga* type.

The abnormal leaves described are atavistic, and the twigs bearing them may be compared to a permanent condition such as obtained in the *Leptostrobi* of the Potomac, a condition which probably obtained also in those forms from the Jura of eastern Siberia described by Heer. *Leptostrobus* may safely be regarded as in the ancestral line of the Pines. *Laricopsis* probably stands in the same relation to *Larix*.

Little can be said in regard to the causes beyond that over nutrition plays no small part in the change. This suggests, at least, that reduced nutrition may have been one of the more important causes resulting in the evolution of the fasciculated condition in *Pinus* and *Larix*.

I wish here to acknowledge the kindness of Dr. Arthur Hollick in indicating to me literature bearing on the fossil conifers.

PLATE I.

PLATE I.

EXPLANATION OF LETTERS USED.

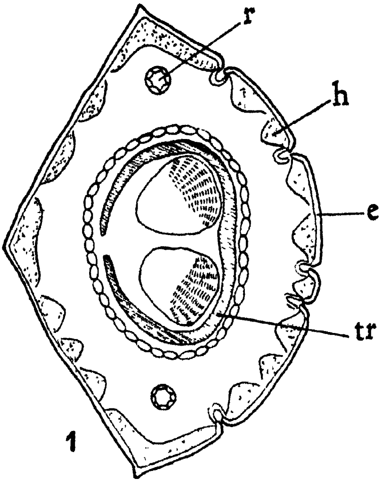
e—Epidermis.	h—Hypoderm.
r—Resin duct.	tr—Trachcary tissue.
1—Hypertrophied scales.	
2—Secondary leaves.	

Fig. 1. Transverse section of normal or secondary leaf. (Schematized).

Fig. 2. Transverse section of hypertrophied scale. (Schematized).

Fig. 3. A shoot bearing both abnormal and normal leaves.

Figs. 1 and 2 are from camera lucida drawings.



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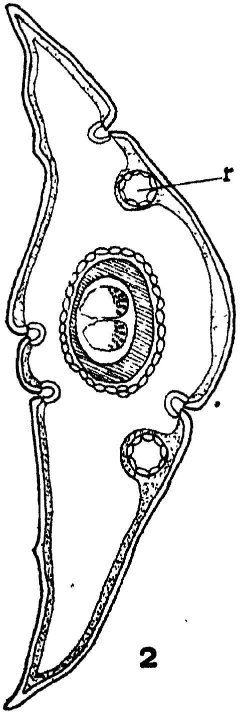

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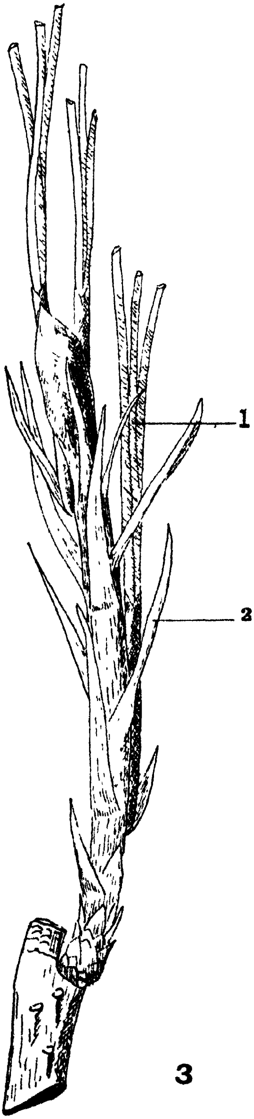

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[ANNALS N. Y. ACAD. SCI., XI. No. 5, pp. 55 to 88, April 20, 1898.]

NOTES ON BLOCK ISLAND.

(Investigation prosecuted with the aid of a grant from the John Strong Newberry Fund of the Council of the Scientific Alliance of New York.)

ARTHUR HOLLICK.

(Read January 17, 1898)

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I. GEOLOGY.

INTRODUCTION.

AT the meeting of the Academy on October 19, 1896, I gave an account of the geology of Block Island, prepared from investigations personally made during the summer of that year, together with all references to the subject on the part of others which I had been able to gather.[1] To this account I would respectfully refer, in order to avoid reiteration, for information regarding the general geologic conditions which prevail and the opinions which have been expressed in relation to them. Last summer I again visited the island, for the special purpose of collecting, if possible, further material representing the Cretaceous (Amboy clay) formation, of which I had obtained indications at the time of my previous visit.

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[1] Geological Notes. Long Island and Block Island. Trans. N. Y. Acad. Sci, XVI (Dec. 15, 1896), 9–18.

Three weeks were spent there, during which period the entire coast line and most of the interior was subjected to critical examination, with the result that several facts not before recorded were noted, and a considerable amount of interesting material was collected. During part of the time I was accompanied by Dr. Lester F. Ward, of the United States Geological Survey.

In order that the general configuration of the island and the several localities mentioned may be understood, I have included a map of the island, prepared from that issued by the United States Geological Survey[1] (see plate II).

PALÆOBOTANY.

One of the most important problems which it was necessary to solve was whether the Amboy Clay Series was represented on the island. Theoretically these clays, which had been previously traced from New Jersey, through Staten Island and Long Island, to Martha's Vineyard, ought to occur also on Block Island and previous observations strongly indicated that such was the fact. Definite evidence, however, was lacking and it was recognized that if a few well-defined and typical species of fossil leaves could be found the question would be settled. Careful and systematic search was therefore made for such evidence, and the result was entirely satisfactory. The material collected was identical in its character and occurrence with that from the other islands mentioned, consisting of ferruginous clay nodules or fragments, containing organic remains, scattered through the Drift, mostly in close proximity to two of the clay-exposures, at Clay Head and Black Rock Point.

About twenty-five specimens of fossil leaves and fruit capable of identification were found, representing fifteen species, all of them Cretaceous in age, and at least nine of them typical of the Amboy clay flora.

Following is the list :

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[1] Rhode Island, Block Island Sheet, 1889.

1. GLEICHENIA GRACILIS Heer (?).

(Pl. III. Fig. 3.)

Gleichenia gracilis Heer, Fl. Foss. Arct., Vol. iii (Kreidefl.), p. 52, pl. x, figs. 1–11 ; p. 98, pl. xxvi, figs. 13 b, c, d.

Our specimen is almost certainly a *Gleichenia*, but the pinnules are more acute and runcinate than in Heer's figures of *G. gracilis.* I prefer, however, to refer it provisionally to this species rather than to found a new one upon such a small fragment.

Locality: Near Black Rock Point, Block Island.

2. DAMMARA MICROLEPIS Heer (?).

(Pl. III. Figs. 9 a, b.)

Dammara microlepis Heer, Fl. Foss. Arct., Vol. vi, Abth. II, p. 55, pl. xl, fig. 5.

The specimens figured on our plate are undoubtedly referable to the organisms which have been called *Dammara* and *Eucalyptus*, from the Cretaceous of America and the Old World. The ones under consideration are, however, smaller than any which have been previously figured and might perhaps be referred to a new species, but, in view of the limited amount of material and its fragmentary condition, I have thought it best to refer the specimens provisionally to Heer's species.

Locality: Ball's Point, Clay Head, Block Island.

3. MORICONIA CYCLOTOXON Deb. and Ett.

(Pl. III. Fig. 10.)

Moriconia cyclotoxon Deb. and Ett., Urwelt. Acrob. Kreidegeb. Aachen und Maestricht, p. 59 [239], pl. vii, figs. 23–27.

In regard to this specimen there can be no doubt. It is one of the most abundant species found in the Amboy clays, at South Amboy, N. J., and is also known from Staten Island and the Arctic regions.

Specimens figured by Herr (Fl. Foss. Arct. Vol. vi, Abth II, pl. xxxiii, figs. 1–9) and by Newberry (Fl. Amboy Clays Monog. U. S. Geol. Surv., xxvi, pl. x, figs. 11–21) are far better for comparison than are the original figures of Debey and Ettinghausen.

Locality: Near Black Rock Point, Block Island.

4. WIDDRINGTONITES REICHII (Ett.) Heer (?).

(Pl. III. Fig. 8.)

Widdringtonites Reichii (Ett.) Heer, Fl. Foss. Arct., Vol. vi, Abth. II, p. 51, pl. xxviii, fig. 5 ; Vol. vii, p. 13, pl. lii, figs. 4, 5.

Frenelites Reichii Ett. Kreidefl. Niederschoena, p. 246, pl. i, figs. 10 a–10 c.

This little fragment of a conifer is referred provisionally to the above species, partly on account of its close similarity and partly because the species associated with it seem to warrant such reference. It is one of the commonest species in the Amboy clays of New Jersey at several localities, and has also been found on Staten Island and Martha's Vineyard.

Locality : Near Black Rock Point, Block Island.

5. THINNFELDIA LESQUEREUXIANA Heer.

(Pl. III. Figs. 4, 5.)

Thinnfeldia Lesquereuxiana Heer, Fl. Foss, Arct., Vol. vi, Abth. II, p. 37, pl. xliv, figs. 9, 10 ; pl. xlvi, figs. 1–11, 12 a, b.

This is another well defined and typical Amboy clay species of wide geographical distribution, which, when found with *Moriconia* would, without any further evidence, be sufficient to determine the horizon in which is occurs.

Found also on Staten Island and Martha's Vineyard.

Locality : Near Black Rock Point, Block Island.

6. JUGLANS ARCTICA Heer (?).

(Pl. III. Fig. 7.)

Juglans arctica Heer, Fl. Foss. Arct., Vol. vi, Abth. II, p. 71, pl. xlii, figs. 1b, 2b.

The fragment figured is apparently the upper part of an ament similar, if not identical, with those described by Heer under the above name. Inasmuch, however, as he also describes and figures aments which can hardly be distinguished from these, under the name of *Myrica longa* (Fl. Foss. Arct., Vol. vi, Abth. II, p. 65, pl. xli, fig. 4b) I have been in doubt under which species to place our specimen.

Locality: Near Black Rock Point, Block Island,

7. SALIX PROTEÆFOLIA LANCEOLATA Lesq.

(PL. IV. Fig. 4.)

Salix proteæfolia var. *lanceolata* Lesq. Fl. Dakota Group, p. 50, pl. lxiv, figs. 6–8.

A large number of varieties and forms have been classed under this species. Our specimen is almost identical with Lesquereux' fig. 8, above quoted.

Locality: Near Black Rock Point, Block Island.

8. SALIX PROTEÆFOLIA FLEXUOSA Lesq.

(Pl. IV. Fig. 5a.)

Salix proteæfolia var. *flexuosa* Lesq. Fl. Dakota Group, p. 50, pl. lxiv, figs. 4, 5.

Recognized also from Long Island and Martha's Vineyard.

Locality: Near Black Rock Point, Block Island.

9. FICUS KRAUSIANA Heer.

(Pl. III. Fig. 1.)

Ficus Krausiana Heer, Fl. Moletein, p. 15, pl. v, figs. 3–6.

In naming our specimen I have been somewhat influenced by the fact that this species is recognized by Lesquereux in the Dakota group of the West (Fl. Dakota Group, p. 81, pl. l., fig. 5), although it might equally well be compared with Velenovsky's *Ficus suspecta* (Fl. Boehm, Kreidef, part iv, p. 10 [71], pl. v [xxviii], figs. 6, 9). The two species, indeed, I am inclined to consider as identical and the comparison of the two is made especially significant when Velenovsky's figure 9 is examined. It has also been recognized in the Martha's Vineyard Cretaceous flora.

Locality: Near South East Point, Block Island.

10. MAGNOLIA WOODBRIDGENSIS Hollick.

(Pl. III. Fig. 2.)

Magnolia Woodbridgensis Hollick, in Newb. Fl. Amboy Clays, p. 74, pl. xxxvi, fig. 11; pl. lvii, figs. 5–7.

There can be little doubt of the identity of our specimen with the above species, especially when compared with figure 7, above quoted.

Locality: Ball's Point, Clay Head, Block Island.

11. LAURUS PLUTONIA Heer.

(Pl. IV. Figs. 6, 7.)

Laurus plutonia Heer, Fl. Foss. Arct., Vol. vi, Abth. ii, p. 75, pl. xix, figs. 1d, 2–4; pl. xx, figs. 3a, 4–6; pl. xxiv, fig. 6b; pl. xxviii, figs. 10, 11; pl. xlii, fig. 4b.

Under this specific name different authorities have placed a large number of fotms from America and the Old World, and several which have received different specific names might equally well be included under it. It is abundantly represented in New Jersey, and has been found on Staten Island, Long Island and Martha's Vineyard.

Locality: Near Black Rock Point, Block Island.

12. CELASTRUS ARCTICA Heer.

(Pl. IV. Fig. 8.)

Calastrus arctica Heer, Fl. Foss. Arct., Vol. vii, p. 40, pl. lxi, figs. 5d, 5e.

For purposes of comparison the figures by Heer, above quoted, are not as satisfactory as those by Newberry. (Fl. Amboy Clays, pl. xiii, figs. 8–18).

It is a common species in the clays of South Amboy, N. J.

Locality: Near Black Rock Point, Block Island.

13. MYRTOPHYLLUM (EUCALYPTUS?) GEINITZI Heer (?)

(Pl. IV. Figs. 1–3.)

Myrtophyllum (*Eucalyptus?*) *Geinitzi* Heer, Fl. Moletein, p. 22 pl. xi, figs. 3, 4.

In referring our specimens to this protean and widely distributed species I have done so provisionally, as the nervation is sparse or wanting in those which exhibit the best outline, while the one in which the characteristic nervation is shown is merely a fragment. Specimens which are entirely satisfactory have, however, been found in New Jersey and on Staten Island, Long Island and Martha's Vineyard.

Locality: Fig. 1, near South East Point; figs. 2, 3, near Black Rock Point, Block Island.

14. EUCALYPTUS? NERVOSA Newb.

(Pl. IV. Fig. 5b.)

Eucalyptus? nervosa Newb. Fl. Amboy Clays, p. 112, pl. xxxii, figs. 3–5, 8.

In the Flora of the Amboy Clays, on the plate above quoted, Dr. Newberry figures two allied species—the one to which I have referred our specimen and another which he calls *Eucalyptus? angustifolia.* Our specimen lacks the tip by which it could be definitely identified, but I have little hesitation in referring it to *E. nervosa.*

The same species has also been identified from Long Island.

Locality: near Black Rock Point, Block Island.

15. TRICALYCITES PAPYRACEUS Newb.

(Pl. III. Fig. 6.)

Tricalycites papyraceus Newb. Fl. Amboy Clays, p. 132, pl. xlvi, figs. 30–38.

Our specimen apparently represents a central lobe of the organism named as above by Dr. Newberry, from Woodbridge, N. J.

The same species has also been been found on Staten Island and Long Island.

Locality: Ball's Point, Clay Head, Block Island.

The evidence afforded by these species is of the highest importance, as it serves to definitely correlate the basal clays of

Block Island with those of Martha's Vineyard to the east, and Long Island, Staten Island and New Jersey to the west, and shows them all to belong to the same Cretaceous horizon.

Inasmuch as a prominent authority has published his opinion that these clays are probably Jurassic in age, I perhaps can not do better than to quote the words of Dr. Lester F. Ward, expressed after an examination of the material now in our possession from the region:

"Those who are capable of supposing that such a flora as this could have flourished in Jurassic time are certainly at liberty to do so, and the geological world will doubtless duly appreciate their courage.[1]"

STRATIGRAPHY.

While engaged in collecting the material previously described other matters of geologic interest were also incidentally noted.

The lithologic characteristics of the basal (Cretaceous) clays always served to distinguish them from the superficial (bowlder) clays above. The latter are best represented on the south shore, at Mohegan Bluffs (see plates V. and VI.) and consist of contorted grayish sandy clay, in which gravel and occasioned bowlders occur, but no organic remains. The Cretaceous clays are exposed at Clay Head (see plate VII), Grace Point, and near Black Rock Point and Old Harbor Point (see plate VIII.). They are plastic and either black from the presence of lignite or else pure white, yellow, red or bluish. Beds of white sand accompany them at the two localities first mentioned.

Observations on dip and strike are of but little stratigraphic importance, on account of the contortion to which the beds have been subjected by glacial action, and such observations as were made merely tended to emphasize this fact, the dip in all cases being toward the north, indicating that the strata had been pushed southward in a series of overthrust folds by the advancing ice front. This was found to be uniformly the case with the basal clays and largely so with the superficial ones, apparently indicating that the latter as well as the former were laid down previous to the advent of the ice.

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[1] *Science*, IV (Nov. 20, 1896), 760.

Photographic views of four of the most interesting localities mentioned were taken from which the accompanying plates were reproduced:

PLATE V. Contorted bowlder clay, south shore, Mohegan Bluffs, looking west, about three-quarters of a mile east of Black Rock Point. Variegated (Cretaceous) plastic clay beneath, in the distance, at extreme left.
Dip of the latter, 60 N. W.; Strike, N. 38 E. and 50 N. W.; N. 10 E.

PLATE VI. View of a portion of the latter exposure, looking east, showing contortions of the bowlder clay.

PLATE VII. White (Cretaceous) plastic clay and sand, overlain with Drift, east shore, Ball's Point, Clay Head.
Dip, 35 N.; Strike, E. and W.

PLATE VIII. Lignitic and white (Cretaceous) plastic clay, overlain with Drift, east shore, near Mineral Spring, about half a mile north of Old Harbor Point.
Dip, 44 N. E.; Strike, E. 20 S.

II. BOTANY.

PRELIMINARY REMARKS.

Although engaged primarily in geological investigations, many notes on the vegetation of the island were incidentally gathered and its connection with the geological features noted. In fact, the study of the flora of any region, particularly that of a restricted one such as an island, is now recognized as being often of the highest importance when considered in connection with the geology, the facts in one often leading to an interpretation of otherwise puzzling problems in the other.

The first essential in such an investigation is to obtain a broad general idea of the vegetation, and for this purpose as complete a list of the plants as possible is necessary, with notes on the relative abundance or scarcity of each species, so that not only may the extent of the existing flora be seen at a glance, but any striking lacunæ be at once noted.

Mr. W. W. Bailey's "Notes on the Flora of Block Island"[1] was made my basis for determining what had been previously recorded on the subject, and with his list constantly by me it was an easy matter, while wandering over the island, to refer to it and ascertain whether any species in question had been noted by him. If found upon the list it was checked off, and if not a memorandum was made and specimens collected.

---

[1] Bull. Torrey. Bot. Club, xx. (June, 1893), 227–239.

Physiographically the flora may be divided into that of hills, the peat bogs and pond holes, the salt marshes, the sand dunes and the salt water, the latter being exclusively algal, except for *Zostera.* The island is practically treeless and hence also devoid of such vegetation as is dependent upon forestal conditions. The bulk of the surface is that of a typical morainal region, with rounded hills and corresponding depressions, many of the latter being occupied by swamps or ponds, often without any visible outlet. Running streams are few and insignificant, and permanent springs occur only in a limited number of localities, mostly close to tide-water. Great Salt Pond, now connected with the ocean by means of an artificial channel, but formerly said to have been fresh water, occupies the center of the island and almost divides it into two parts, while between the eastern and western borders of this pond and the ocean are low narrow strips of dunes and sand beaches. The remainder of the coast line is more or less precipitous and is strewn with boulders, washed out from the adjoining land. The soil, except that of the limited dune and sand beach areas, consists of the boulder till and gravel. There are no rock outcrops anywhere exposed, and the geological conditions preclude the probability of any being within hundreds of feet of the surface. Probably all the land capable of it is, or has been at some time, either under cultivation or used for pasturage. Such, in brief, are the conditions under which the vegetation exists to-day on an isolated island about eleven square miles in area.

ADDITIONS TO THE FLORA.

Mr. Bailey enumerates in his list 285 species of Spermatophyta and 9 Pteridophyta, to which I was able to make the following additions, collected between July 8th and July 30th.

1. *Zostera marina* L. Abundant in salt water.
2. *Panicum sphærocarpon* Ell. } Abundant on the dry hills.
3. *Panicum pubescens* Lam. }

Probably included by Mr. Bailey under *P. dichotomum* L.

4. *Juncus acuminatus* Michx. Abundant in the peat bogs. Commonly proliferous.

5. *Smilax rotundifolia* L. Rare. Only a few scattered plants, in widely separated localities on the south end of the island.

6. *Sisyrinchium Atlanticum* Bicknell. Common. Probably included by Mr. Bailey under *S. anceps* Cav.

7. *Populus balsamifera candicans* (Ait.) A. Gray. Sparingly established in certain swamps. Common in cultivation.

8. *Salix cordata* Muhl. Common in many swamps and along roadsides. Occasionally planted.

9. *Salix cordata angustata* (Pursh) Anders. Abundant in one swamp near the south side of Great Salt Pond.

10. *Salix purpurea* L. Abundantly and thoroughly naturalized along roadsides.

11. *Rumex obtusifolius* L. Sparingly, in a ditch along south side of Main St.

12. *Glaucium Glaucium* (L.) Karst. A few plants, on the sand hills near Grace Point.

13. *Roripa palustris* (L.) Bess. Sparingly in a ditch along south side of Main St.

14. *Trifolium incarnatum* L. One plant, in a field at the south end of the island. Probably introduced with other clover and hardly naturalized.

15. *Trifolium procumbens* L. Not common.

16. *Acalypha gracilens* A. Gray. Common in dry open fields. Usually stunted. Probably included by Mr. Bailey under *A. Virginica* L.

17. *Vicia sativa* L. Common.

18. *Hudsonia tomentosa* Nutt. Abundant on the sand hills near Grace point.

19. *Onagra Oakesiana* (A. Gray) Britton. Not rare near the shore. Probably included by Mr. Bailey under *Œnothera biennis* L.

20. *Lysimachia quadrifolia* L. Common.

21. *Trientalis Americana* Pursh. Common.

22. *Asclepias pulchra* Ehrh. Common.

23. *Sericocarpus asteroides* (L.) B.S.P. Abundant in a limited locality at the south end of the island.

24. *Gnaphalium purpureum* L. Not common. Found with *G. uliginosum* L. in the vicinity of Clay Head.

With the above additions the list now comprises 309 Spermatophyta and 9 Pteridophyta, but there is no doubt that it could be largely increased if collections were made in the spring and autumn. I was unfortunate in having explored the same region as did Mr. Bailey, at the same time of year, so that I was able to accomplish but little more than to pick up a few species which he had somehow missed.

DISCUSSION OF THE FLORA.

If the flora be now examined as a whole several significant facts may be noted. Many curious lacunæ will at once attract attention, as remarked by Mr. Bailey, and not only are species wanting which one might reasonably expect to find, but so also are whole genera and even families.

For example, the Liliaceæ are not represented, and of the Smilaceæ only two species (*Smilax rotundifolia* L. and *S. glauca* Walt.) were found in very limited numbers. The Boraginaceæ are wanting and, except for a few scattered trees of *Nyssa aquatica* L., the Cornaceæ would be likewise. The genera *Cornus*, *Vaccinium* (excluding the cranberry), *Veronica*, *Meibomia*, *Lespedeza* and *Baptisia* are entirely absent. Only four species of *Carex* were found, one *Pycnanthemum* and one *Viburnum*, while many other species are represented by only a few individuals. Among the species which might be reasonably expected to occur, but which were not seen, may be noted *Solanum Dulcamara* L. and *Verbascum Blattaria* L., which usually follow in the wake of civilization; *Hibiscus Moscheutos* L., *Vernonia Noveboracensis* (L.) Willd., *Iva frutescens* L., *Kneiffia linearis* (Michx.) Spach., *K. pumila* (L.) Spach. and *Limodorum tuberosum* L. The absence of the latter would perhaps not be remarkable except for the fact that its usual companion, *Pogonia ophioglossoides* (L.) Ker. is quite abundant.

This list of lacunæ could be readily extended by a careful analysis of the flora, but it should also be borne in mind that more thorough search might and probably would reveal the existence of species which have thus far escaped notice.

The flora is morainal in its general character, except in the peat bogs and on the limited sand-dune and sea-beach areas, and has its nearest analogue in that of Montauk Point.[1] In fact, if we could imagine Montauk Point to be despoiled of its few remaining trees and converted into an island it would bear a striking resemblance, geologically and botanically, to Block Island.

CAUSES WHICH HAVE DETERMINED AND MODIFIED THE FLORA.

In discussing the causes which have determined the location of any flora and subsequently modified its characters, two prominent factors nearly always have to be considered—the geological and the human. Each of these may have been instrumental in both introducing and eliminating certain species, and the discussion of a flora cannot be considered as complete unless they are taken into consideration. The influence of man is usually so obvious as to appeal at once to any observer or else it is a matter of more or less definite record. The geological influence however is often so obscure and has its beginning at such a remote period that it usually escapes attention. In its widest application this includes atmospheric and ocean currents, soil, climatic changes, changes of level, etc.

From a study of the existing geological and floral conditions, as I have elsewhere attempted to demonstrate,[2] the indications are that at the close of the Ice Age there was a continuous strip of land, except for certain river outlets, extending from what is now New Jersey to the southeastern New England coast, with a large body of fresh water occupying the deepest parts of what is now the basin of Long Island Sound. This strip consisted of an elevated portion along the northern border, formed by the terminal moraine, left behind on the final retreat of the ice, and a plain region to the south, of varying width, representing what remained of the old Tertiary coastal plain, which formerly extended out to what is now the 100-fathom contour. The flora which had been driven southward by the invasion of the ice returned when the ice receded, only such species becoming established, however, as could exist under the changed conditions. Fluctuations of level occurred; the final epoch, extending to the present time, being one of depression, during which the strip of land was gradually disintegrated and separated into a series of islands, some of which exist to-day as Long Island, Block Island, Martha's Vineyard and Nantucket, while the basin of Long Island Sound became filled with salt water.

---

[1] See "A trip to Montauk Point." Arthur Hollick, Bull. Torrey Bot. Club, xviii (August, 1891), 255, 256.

[2] See "Plant Distribution as a Factor in the Interpretation of Geological Phenomena," etc. Trans. N. Y. Acad. Sci., xii (1893), 189–202.

If we consider the geological features of these islands and compare their floras, we may note that all except Block Island still have a greater or less area of the plain region remaining with them, upon which a characteristic flora finds a home. Block Island has lost all of its plain region and accompanying flora and is now merely an isolated portion of the terminal moraine, with small areas of modern sand-beach and dune formations, affording a home only for such species as can exist under those conditions. We may thus understand one of the causes which has determined the location and character of the flora and one of the reasons why it is so limited in the number of its species.

Further than this, if the submarine contours of the vicinity are studied it will at once be seen that a deep channel extends almost entirely around Block Island. This fact is especially emphasized if the twenty-fathom contour is traced out and continued around our coast line from Cape Ann to Staten Island. (See accompanying chart, plate IX.) From such a tracing the fact is evident that if we could imagine the coast to be subjected to elevation, until the twenty-fathom contour became the coast line, Block Island would yet remain an island, or perhaps a peninsula-like projection connected with the eastern end of Long Island by a narrow isthmus, while Martha's Vineyard and Nantucket would be part of the mainland of New England.

The indications therefore are that Block Island was the first portion of the strip of land to be isolated and converted into an island. The flora of the plain region, coming largely from the south and possibly always having existed close to the ice front,[1] would be the first to advance and occupy the ground, while that of the moraine, being more of a northern type, could not become established until the conditions due to glaciation northward had become modified so that it could exist there and become distributed and Block Island, on account of its morainal character, would only be favorable for the flora which was the last to return. These geological changes then were probably what determined the general character of the flora in the first instance, and the next question for us to answer is what subsequent causes served to modify it into its present condition.

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[1] It is well known that the floras of many regions where glaciers occur, exist and flourish, not only up to the ice front, but even upon the débris covering the ice.

In the accounts of the earlier explorers and settlers the trees of the island are frequently mentioned and there is no doubt that it was extensively wooded at that time, but with what species there does not seem to be any record, except vague reference to pine, oak, beech, hickory, etc. In many of the peat bogs may yet be found large stumps, together with roots and branches, providing us with evidence that these early accounts were true. I saw one stump, about three feet in diameter, which had been dug out of a swamp at Clay Head, while at Old Harbor Point, in a swamp which had become exposed by the action of the waves, were found numerous stumps, roots and branches. As before stated, the island is now practically treeless, except for the few wind-lashed and stunted individuals in the vicinity of dwellings or in sheltered swamps and hollows. The extinction of the arboreal flora was undoubtedly due directly to the necessities of civilization, not only for the purpose of land cultivation and pasturage, but also for lumber and fire wood. On account of their isolated position, the population, in its early days, had to depend almost entirely for subsistence upon what could be gathered from or cultivated on the island. The disappearance of the trees is, therefore, readily accounted for by the direct influence of man, and to this influence was, of course, indirectly due the extinction of such herbaceous plants as could only exist under forestal conditions. Subsequent cultivation and pasturage destroyed many more, and the complete isolation of the island rendered the re-establishing of species by natural agencies a matter of time or fortuitous circumstances.

A limited number of species have, of course, also been introduced, purposely or accidentally, by human agency and are now part of the wild flora, and further additions will doubtless be made in the same way in the future, but as a study of plant distribution Block Island will always be of interest chiefly on account of the geological causes which determined the character of its flora long before the advent of man.

III. MISCELLANEOUS NOTES.

ARCHÆOLOGY.

Around the shores of Great Salt Pond and on the sand dunes which border the western shore of the island evidences of former occupation by the Indians are numerous. Kitchen middens are exposed in several street cuttings; implements are often found scattered over the surface of the ground in certain localities and skeletons have been unearthed from time to time.

In many places the kitchen midden accumulations were so obvious that it was impossible for me to ignore them entirely. They were found to consist of the customary collection of oyster and other shells, bones, pottery fragments, fire-cracked stones, charcoal, finished implements, rejects, flakes, chips, etc. An attempt was made to calculate the relative abundance of the several kinds of molluscs represented, with the following result:

1. Oysters; 2. hard clams (*Venus*); 3. soft clams; 4. mussels; 5. pectens; 6. long clams (*Mactra*); 7. limpets; 8. land snails; 9. occasional conch and razor shells.

The finished implements found were two axes, of a plagioclase igneous rock and three arrow points, all of quartzite. The flakes and chips were found to be mostly of white quartz and quartzite, with chert and jasper sparingly represented.

In the sand dunes are many old fire places, mostly buried by the sand which has drifted over them. They could generally be located, however, by the thrifty nature of the turf on the surface immediately above. Indeed, my attention was first called to their presence by noticing the patches of short green turf, scattered at intervals through the tall grass of the dunes. Upon digging down to a depth of from two to ten inches, I invariably found accumulations of charcoal, cobble stones, shells and the bones and teeth of animals. A number of the latter were collected and subsequently submitted to Dr. Bashford Dean, of Columbia University, for examination, to whom I am indebted for the following list:

Sturgeon, numerous plates.
Bluefish, jaws and teeth.
Swordfish, fragments of a skull and premaxillæ.
Fish vertebræ, not identified.
Porpoise (?), fragments of ribs.
Seal, fragment of a rib.
Vertebræ and tibia of a bird, possibly a swan.

The indications are that the island would prove a rich field for investigation by anyone interested in archæology, as a fair amount of material may be obtained by mere surface scratching, and systematic search would doubtless reveal much more. Aside, however, from the value of the material which might be collected, an insight would be obtained into the fauna which formerly inhabited the island and its surrounding waters—information which would be of great interest to the zoölogist.

NOTE.—After having made the few archæological observations above recorded I learned by accident that explorations were being made by others specially interested in the subject. This information caused me to abandon any further investigations in that direction, in order not to anticipate any of the work under way, the results of which will doubtless be published in due time through other channels.

ZOÖLOGY.

As might be expected, the existing fauna is comparatively sparse and is evidently very meagre compared to what once existed on the island. In fact, the scarcity of animal life is sure to at once attract the attention of the observer from the mainland.

Tree-loving birds are conspicuous by their absence, and I was curious to know how the robins, which were more or less abundant, were in the habit of nesting. Bank swallows, red-winged blackbirds and meadow larks were the birds most in evidence, and I found a nest of the latter, with four eggs, on July 20th. A bird that I identified with reasonable certainty as the bay-winged sparrow was seen in considerable numbers, evidently breeding freely, as I found two nests, one with three eggs on July 13th, the other with two on July 25th. Unless my previous experience is at fault, all these nests represent very late broods, and this feature seemed to me to be a fact of sufficient interest for record.

An interesting feature of the molluscan fauna is the immense numbers of *Littorina littoria*, the "periwinkle" of the Old Word, which is now by far the most abundant shell-fish on the shores. In places the rocks were found completely covered by them, to the exclusion of all native species. So far as I have been able to ascertain, the first record of the occurrence of this species in America was in 1857, at Halifax, Nova Scotia. It 1873 it was reported from Prince Edwards' Island, and in 1875 from Provincetown, Cape Cod. It was next found at Wood's Holl and Newport, and on Loyd's Neck, L. I., and on Staten Island in 1888. I do not know of its previous record from Block Island, and am not informed as to its occurrence south of Staten Island. As it lives upon rocks, the sandy shores of New Jersey would probably not be a congenial habitat for it, and might limit its farther southward migration.

Frogs and spotted turtles are plentiful, and I occasionally came across a few small striped snakes, but, except for those mentioned, the faunal elements were not obvious and would have to be searched for in order to be observed.

PLATE II.

PLATE II.

Map of Block Island, reproduced, with alterations, from the Rhode Island, Block Island Sheet, U. S. Geological Survey (1889).

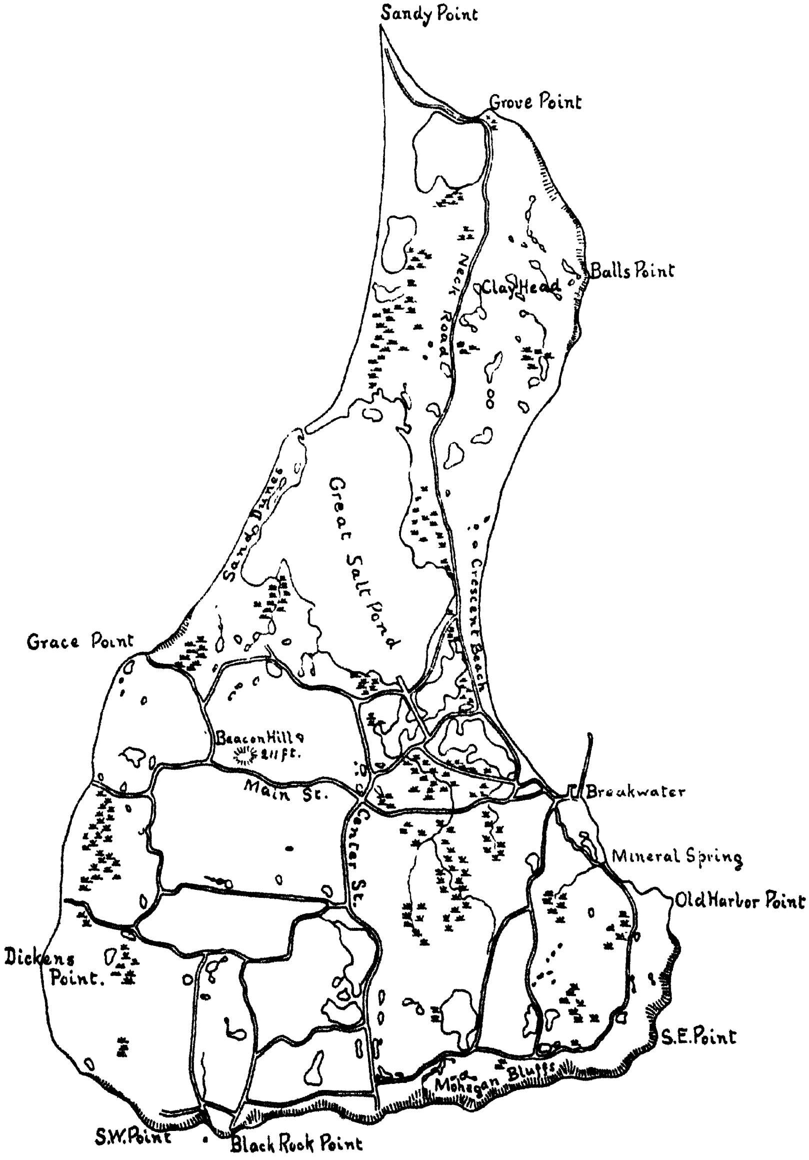
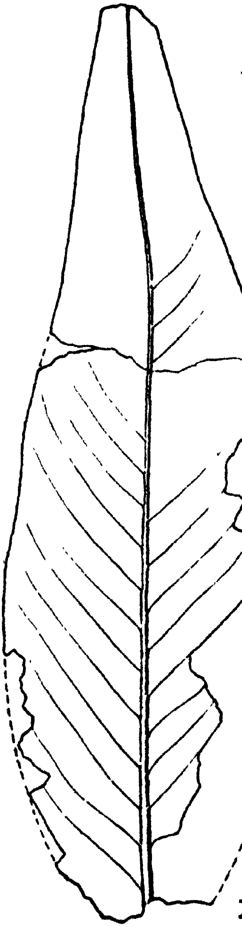

Sandy Point
Grove Point
Neck Road
Clay Head
Balls Point
Sand Dunes
Great Salt Pond
Crescent Beach
Grace Point
Beacon Hill
211 ft.
Main St.
Breakwater
Center St.
Mineral Spring
Old Harbor Point
Dickens Point.
S.E. Point
Mohegan Bluffs
S.W. Point
Black Rock Point

PLATE III.

PLATE III.

PAGE.

Fig. 1. *Ficus Krausiana* Heer. Southeast Point. 59
Fig. 2. *Magnolia Woodbridgensis* Hollick. Ball's Point . . . 60
Fig. 3. *Gleichenia gracilis* Heer (?). Black Rock Point. . . 57
Figs. 4, 5. *Thinnfeldia Lesquereuxiana* Heer. Black Rock Point. 58
Fig. 6. *Tricalycites papyraceus* Newb. Ball's Point. 61
Fig. 7. *Juglans arctica* Heer (?). Black Rock Point. . . . 58
Fig. 8. *Widdringtonites Reichii* (Ett.) Heer (?). Black Rock Point 58
Figs. 9a, 9b. *Dammara microlepis* Heer (?). Ball's Point . . 57
Fig. 10. *Moriconia cyclotoxon* Deb. and Ett. Black Rock Point. 57



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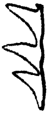

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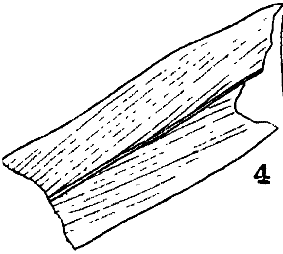

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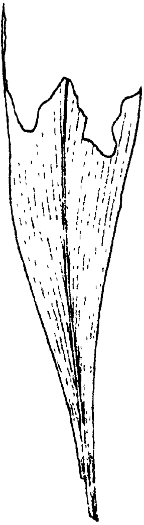

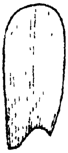

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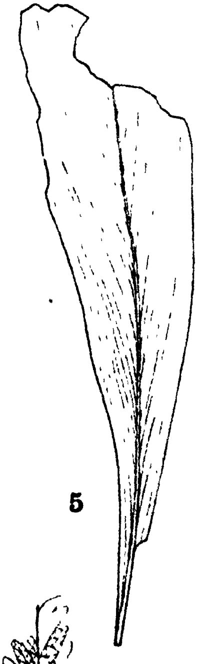

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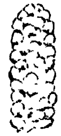

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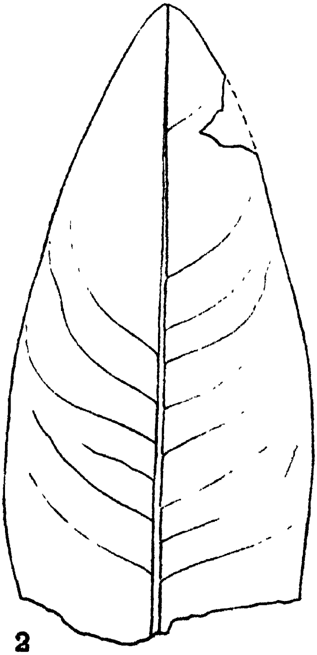

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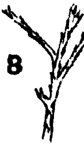

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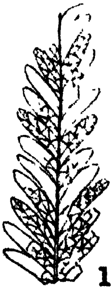

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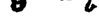

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PLATE IV.

PLATE IV.

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Figs. 1–3. *Myrtophyllum* (*Eucalyptus ?*) *Geinitzi* Heer (?). Black Rock Point	60
Fig. 4. *Salix proteæfolia lanceolata* Lesq. Black Rock Point.	59
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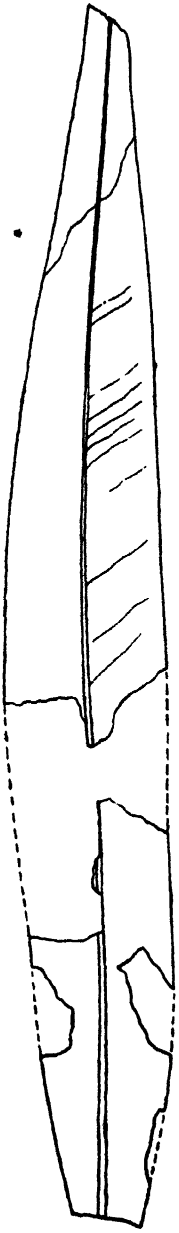
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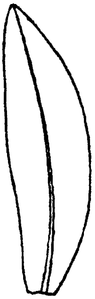
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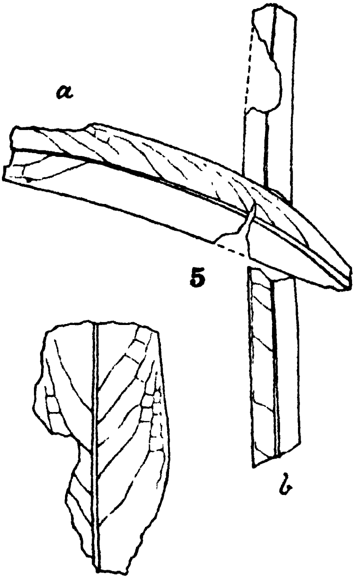

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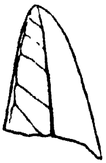
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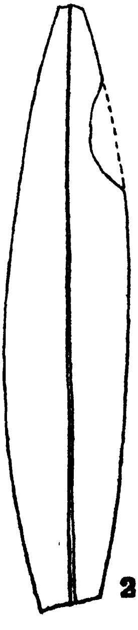
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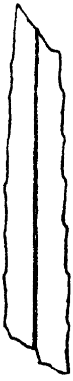
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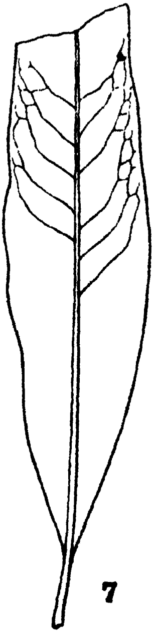
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PLATE V.

PLATE V.

General view of Mohegan Bluffs, east of Black Rock Point, Block Island. View is to the west.

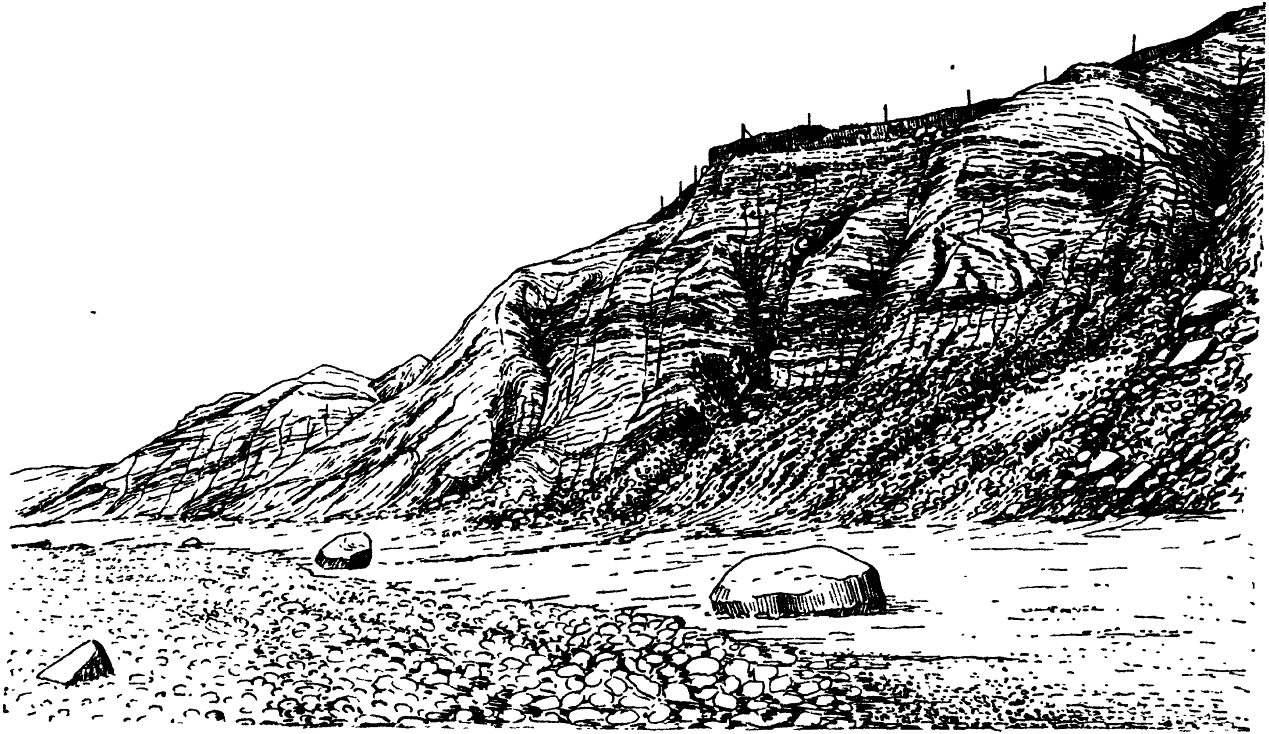


PLATE VI.

PLATE VI.

View of portion of Mohegan Bluffs, Block Island, shown in Plate V., looking eastward.

PLATE VI.

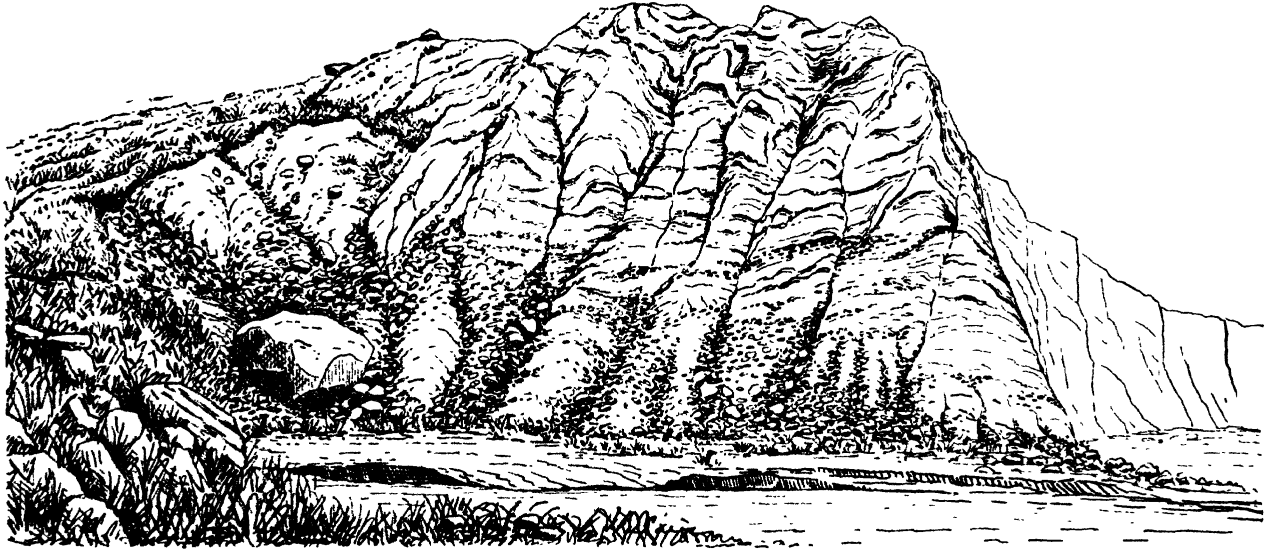


PLATE VII.

PLATE VII.

Exposure of white plastic (Cretaceous) clay and sand at Ball's Point, Clay Head, Block Island.

PLATE VII.

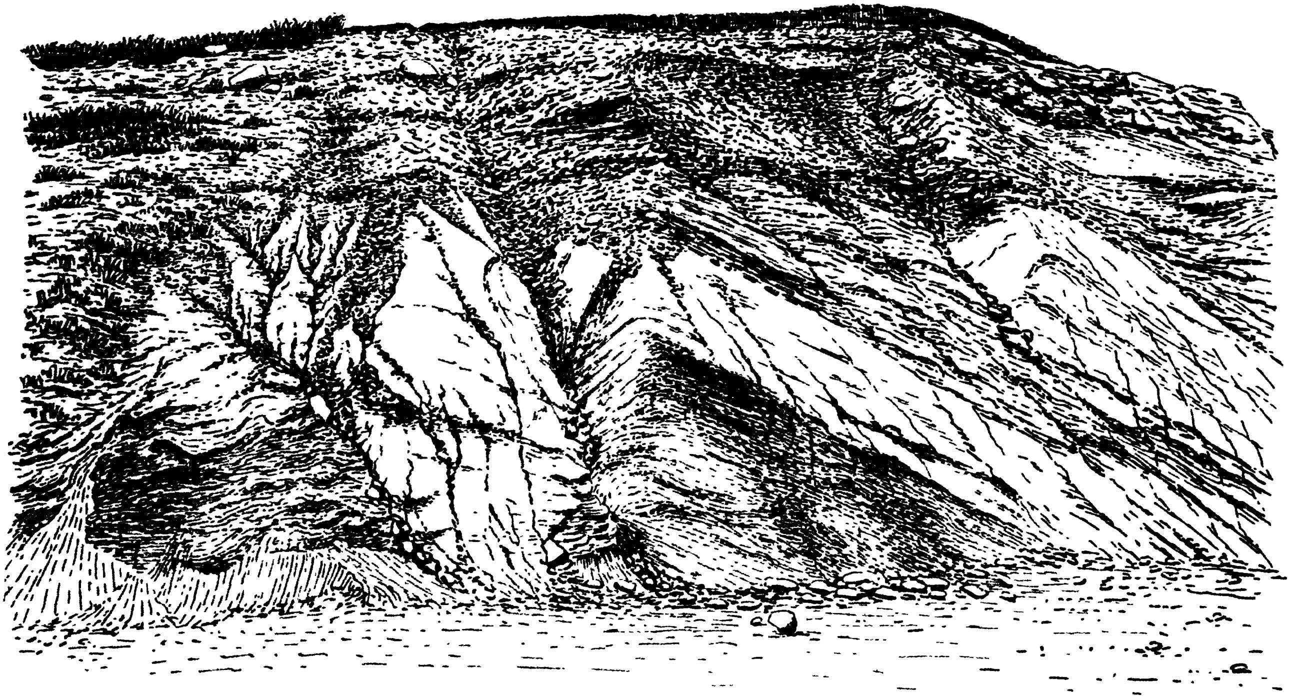


PLATE VIII.

PLATE VIII.

Exposure of lignitic and white plastic (Cretaceous) clay, Mineral Spring, north of Old Harbor Point, Block Island.

PLATE VIII.

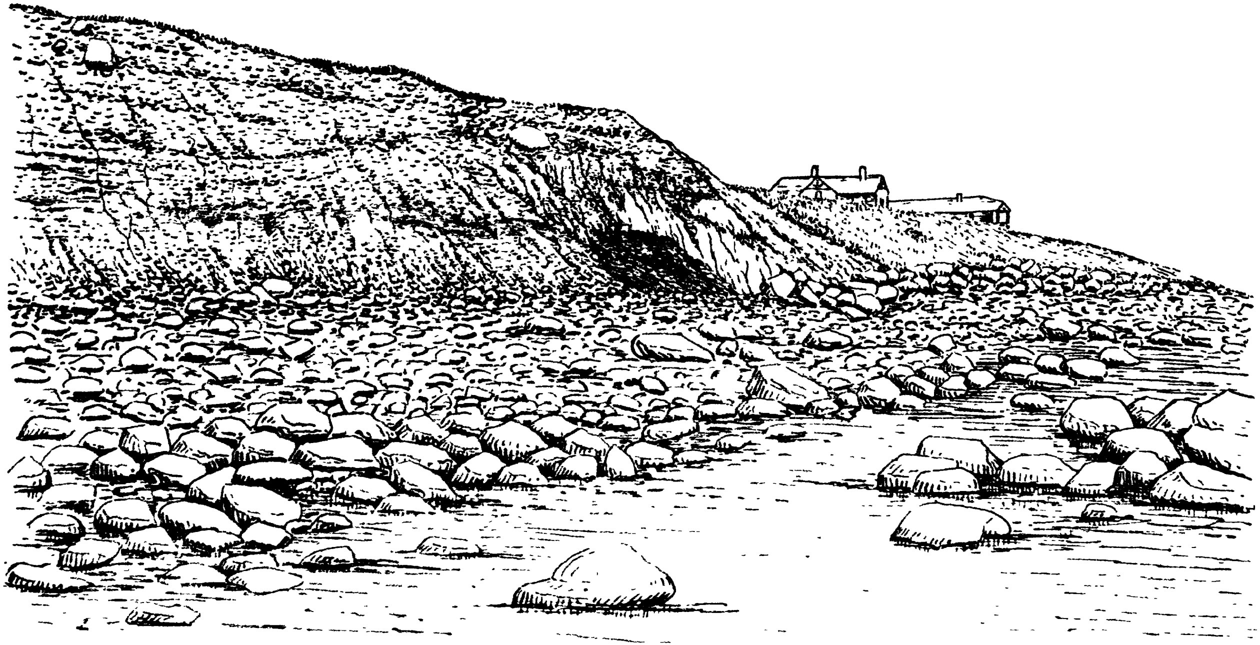


PLATE IX.

PLATE IX.

Chart of the Atlantic Coast, from Cape Ann to Staten Island showing the location of the twenty-fathom contour.

[ANNALS N. Y. ACAD. SCI., XI, No. 6, pp. 89 to 116, April 20, 1898.]

THE USE OF THE DUDLEY "STREMMATOGRAPH" IN DETERMINING STRESSES IN RAILS UNDER MOVING TRAINS.

P. H. DUDLEY, C.E., PH.D.

(Read February 7, 1898)

[PLATES X–XIII.]

ON former occasions I have presented to the Academy diagrams of railway tracks showing the undulations of different weights of rails under moving loads as taken by my Dynagraph and Track Indicator car.

Attention was directed to the marked reduction in the undulations in the stiffer and heavier rails put into service in recent years as a result of the earlier investigations.

I also stated that with rails of a given stiffness, surfaced in the track to their highest condition, the trackmen can only reduce the undulations to definite minimum limits for the wheel loads; therefore, all undulations under the moving wheel loads of locomotives and cars with their increased dynamic effects due to speed can not be entirely reduced.

To carry the trains, the rails not only deflect under the wheel loads, but the ties, ballast and road-bed are compressed until the total resistance equals the load. Action and reaction must be equal and before the latter is obtained for heavy loads on light rails rapid destructive work is done upon the ties and ballast, requiring frequent surfacing to keep the track up to its proper standard. The destructive work on the ties and ballast under stiffer and heavier rails is reduced as well as the necessary labor to keep them in surface.

The weight of the locomotives and cars can only be transmitted to the road-bed through the wheel contacts on the rails, which produces a general deflection of the rails under the wheel base of the locomotives and cars, the greatest deflection being directly under the wheels.

To carry and distribute the wheel loads to the ties, ballast and road-bed, the rail acts as a girder, the metal in the rails directly under the wheels above the neutral surface is in compression, while that below the neutral surface is in tension.

On and near the supporting ties, shearing stresses are set up extending through the web of the rails as the wheels pass over the rails.

The span of the deflection of the rails under the wheels is longer as a rule than the tie spacing, and in a short distance on either side of the wheels the nature of the stresses is reversed, the head of the rails being in tension and the base being in compression.

The picture on the screen is a representation of the wheel loads and base of a Boston and Albany 100-ton locomotive standing on 95-lb. rails, showing in figures the actual depression of the rails, ties and road-bed under the static loads. The rails under moving trains rise slightly in front of the pilot. [See Plate X., Fig. 2.]

The dotted line directly over the rail indicates its general depression under the wheel loads and base of the locomotive.

The vertical scale is enlarged to render the depressions more distinct; the greatest deflections in the rails and road-bed being directly under the wheel contacts.

The truck wheels carry 20,350 lbs. per pair; the drivers 37,500 lbs. per pair; the front tender wheels 18,500 lbs. per pair, and the rear ones 23,500 lbs. per pair. The depression and deflection shown for one rail is, therefore, for wheel loads only one-half of that per pair of wheels. Locomotives with much greater weights on the drivers are in general use.

The depression under the front truck wheel of the engine was 0.094 of an inch; between the wheels 0.086 of an inch, and under the rear truck wheel 0.100 of an inch.

In the wheel space between the engine truck and front drivers the depression was 0.088 of an inch; under the front driver 0.138 of an inch; in the wheel space between drivers 0.096 of an inch, and under the rear drivers it was 0.140 of an inch. In the wheel space between rear driver and front wheel of the tender truck the depression was 0.086 of an inch; between front tender truck wheels 0.100 of an inch, showing abnormal conditions in the track, and under rear wheel of front tender truck 0.099.

In the wheel space between the two tender trucks 0.095 inches, and under front wheel of rear tender truck 0.113 of an inch and on the wheel space 0.106 inches and for the rear wheel 0.113 inches.[1]

A measurement of a short gauged length, say 5 inches, of the base of the rail under the wheels showed extension, while between the wheels, compression. The measurements were not made in this manner, as it requires more time than can usually be obtained in the main line, but with a micrometer in one position on the rail each wheel and center of wheel space being stopped over the micrometer.

Apparent stresses per square inch of the metal for the extreme fibers of the base of the rail ran as follows in one position of the rail for the different wheels and centers of the spaces:

	Tension in pounds	Compression in pounds.
Front engine truck wheel,	6780	
Center of wheel space,		1530
Rear engine truck wheel,	5340	
Center of space between rear engine truck wheel and driver,		3050
Front driver,	9160	
Center of space between drivers,		3050
Rear driver,	9920	
Center of space between driver and front tender wheels,		2290
Front truck front tender wheel,	3820	
Center of space between wheels,		760

---

[1] From Report for 1895, of Tests of Metals and other Materials for Industrial Purposes, made with the U. S. Testing Machine at Watertown Arsenal. Mr. James E. Howards, *Railroad Track Experiments*. By redriving the spikes in the ties, taking up all looseness between the rail and ties, the deflections and stresses were reduced over one-third in amount.

Front truck rear tender wheels, ...	3820	
Center of space between tender trucks,......		1530
Front wheel rear tender truck, ...	6100	
Center of space between wheels, ...		0000
Rear wheel of rear tender truck, ...	6870	

The shaded ballast under the ties in Plate X., Fig. 2 is an ideal representation of the distribution of the pressure of the wheel loads through the rails, ties and ballast to the road-bed, the darker portions representing the most intense pressures. Under moving trains the wheel loads are transmitted as a series of waves of pressure to the ballast and road-bed.

A series of alternating stresses run through the rails in consonance with the speed of the trains, the waves of greatest intensity being between the ties. Some of the slides will show that the tremors and vibrations of the rails are very decided under the wheels passing in quick succession. The duration of the greatest intensity of the stress of the metal is very short per lineal inch, being only a fraction of a second for the high speed trains, less than 1/250 of a second for a speed of 40 miles per hour; while the maximum stress increases with the speed, the duration of greatest intensity decreases.

A rail in the track, like any other girder, to carry its loads without taking a permanent set, must not have the metal stressed beyond its elastic limits and it should be much less for a proper factor of safety.

The diagrams of the earlier steel rails, which I have previously shown, indicate that nearly all the rails had taken more or less permanent set; therefore, the fiber stresses in the rails at times had exceeded the elastic limits.

This important fact must be borne in mind, for the stresses which occurred in the early steel rails, even for the lighter equipment, were greater than I shall report for the present 80-lb. rails. The stresses in rails may be much greater than would be permissible in bridge members, for in the latter they are of several seconds' duration and the material a much lower grade of steel. High stresses in rails are not of recent origin, but occurred a few times daily in the early rails. The rails would stand some millions of repetitions of stress nearly up to the elastic limits before fracture would occur. If such stresses are of a half hour or longer intervals some recovery in the metal takes place; but when fracture does commence, it seems to start between individual adjacent mineral aggregates, rather than through them, becomes progressive, and in many cases the complete rupture of the section may take one or more years of further service.

The tests of many of the earlier steel rails show that the elastic limits only ranged from 35,000 to 48,000 lbs., the ultimate strength being about twice those amounts respectively.

In the testing machine it takes 30,000 pounds tension to elongate one square inch of steel per lineal inch 1/1000 of an inch and the same force to compress it, which was nearly all the early steel rails permitted the extreme fibres in the base of the rail to be extended or compressed before set would occur. This margin was too small, and as the traffic increased it was impossible to maintain the tracks to a high standard even at a very large cost for labor. These facts lead me to urge the adoption of stiffer and heavier rails with higher elastic limits which would reduce the fibre stresses much below the elastic limits of the steel, increase the factors of safety and not require so much labor to maintain them to a high standard in the track.

When I look over the diagrams of the earlier steel rails, it is difficult to realize that it is only fifteen years since I designed the pioneer 5-inch 80-lb. steel rail for U. S., which was rolled for and put into service in 1884, by the N. Y. C. & H. R. R.R.

The Pennsylvania Railroad and others soon followed with 5-inch sections of 80 or 85 lb.; 80 lbs. becoming very general on Eastern Trunk Lines, forming a distinct epoch in the development of American Railways.

It takes many years to change the section of rails on a long main line, while the design of new equipment and construction is but a few months' work and easily keeps in advance of the permanent way improvements.

The slide on the screen is from a photograph of the "Empire

State Express" on the third day of its installation in November, 1891, taken near Syracuse when running at 60 miles per hour on 65-lb. rails before the entire main line had been relaid with 80-lb. The photograph, and another one of the same train, which will be shown, were taken by Mr. A. P. Yates, Official Photographer of the N. Y. C. & H. R. R. R. Co. [See Plate XII., Fig. 1.]

The installation of the "Empire State Express," the fastest long distance train ever attempted, aroused a great deal of discussion among railway men as to the possibility of maintaining it for any length of time. It was considered by many a doubtful experiment. But few people realized how high the standard of the track had been raised in the past few years and the decided advantages of the stiff 80-lb. rails in most of the track for such high speeds.

It is exceedingly interesting that one picture was obtained when running on 65-lb. rails as showing the depression of the rails under the engine, tender and front truck of the first coach. The picture will become historic. I have studied an enlargement of the picture nearly equal to that now on the screen and have traced the general depression of the rails and ties as stated. The wave of the rising rail preceding the pilot can also be seen.

A train at 60 miles per hour runs 88 feet per second, which is longer than the entire wheel base of the engine, tender and front truck of the first coach, making, in the case of the "Empire State Express," eleven wheels to run over a given point in the rail per second, each wheel causing and reversing stresses of several thousand pounds, violent tremors and vibrations being set up in the rails. The permanent set in the 65-lb. rails of the next track is very apparent. The 65-lb. rails were replaced by 80-lb. rails in 1892.

The majority of the earlier 60 to 65-lb. steel rails had all taken a set in the tracks, the ties were cut out from ½ to 1½ inches in depth under the rails, and the undulations per mile ranged from 8 to 12 feet. The slide on the screen is from a photograph taken of the "Empire State Express" at 60 miles per hour on 80-lb. rails. I have not been able to trace the depression of the rails under the moving train; nevertheless it occurred, but to much less extent than on the 65-lb. rails. [See Plate XII., Fig. 2.]

On the diagrams of the heavier rails of recent years, the undulations per mile on the 80-lb. rails have been reduced to less than three feet, and on the 100-lb. rails to less than two feet; as measured by my car, the rails being in good surface; the ties showing but little abrasion under the rails.

In 1883 it was considered by many that a 5-inch 80-lb. rail was stiffer and heavier than necessary, while others thought it would provide for the future development of the railways for all coming time.

The rails once in the track furnished a practical demonstration of the value of stiffness in rails and soon led to an increase of speed and heavier equipment, increasing the fibre stresses in the 80-lb. rails over that for which they were designed to sustain.

In March, 1892, my 6-inch 100-lb. rail section was rolled, the first to go into service in the United States, to again reduce the fibre stresses in the rails to meet requirements of increasing traffic. To date there are several thousand miles of 100-lb. rails in use in this country.

In the last decade all of the Eastern and many of the Western trunk lines have been laid with stiff rails for the purpose of keeping the fibre stresses in the rails down to safe and economic limits, though this feature of the matter has received but little discussion.

In 1888 in connection with Mr. James E. Howard, of the Watertown U. S. Arsenal, I had one of the Boston and Albany passenger locomotives weighed and ran it onto rails in the main track, the upper side of the base of the rail having been prepared with prick punch marks practically 5 inches apart, the space having been measured with a micrometer to 1/10,000 of an inch. The measurements were repeated after the locomotive was on the rails to ascertain the compression of the base of the rail between the wheels and the elongation under the wheels.

From the results the apparent stresses in the rails were computed for the static loads which were probably too low as the largest stress was only 13,500 lbs. on a 4½-inch rail for a load of 16,000 lbs. on drivers.

Mr. Howard in 1893, 4 and 5 repeated the tests on other railroad tracks and heavier rails and found apparently higher stresses. I repeated the experiments on rails in the tracks, and the results seeming low I had solid piers erected and with rails 30 feet long under known stresses I found my results were too low.

With micrometers designed for the work the results for static loads should be fairly accurate.

The determination of the stresses or rather the compression and elongation of the metal in the base of the rail under moving trains is a much more difficult problem, or rather a series of problems, than it is for static loads, and I am not aware that any one has attempted their solution before I attacked them the past year with my Stremmatograph and its accessories.

A mathematical expression for the stresses of rails under moving trains, its span for the ties and wheel spacing, the deflection and compression of the ties, ballast and road-bed, has not been fully determined, though many efforts to do so have been made.

Such a formula would also have to consider the many conditions of the path not only described by the centre of gravity of the locomotive, tender and each car of the train, but also those of the rotating wheels, their mass and speed, the smoothness of the rails and the more or less sudden application of the loads.

The principle of the Stremmatograph is to record on a moving metallic strip the molecular compression or elongation of the metal in a given length of the base of the rail, induced by the stresses, produced by each wheel of the moving trains under the many conditions of service.

These records can be measured by filar micrometers under a microscope and then from the modulus of elasticity of the steel compute the stresses which produce the given compression or elongation per square inch of the extreme fibres in the base of the rail. [See Plate X, Fig. 3.]

The object of the Stremmatograph is to convert rails of any section and weight, of any system of permanent way construction into testing machines in the track and show how much they are stressed due to the wheel loads and spacing of any type of locomotives and cars moving over the rails at the different speeds of service.

It is to replace what is now mere conjecture by reliable information that further progress may be made in the interest of greater safety and economy. [See Plate XI., Fig. 1.]

The picture on the screen shows the first form of the Stremmatograph attached to the base of the rail between the figures 2 and 3 on the scale bar, and under the front driver of the freight mogul engine, No. 596, of the New York Central & Hudson River Railroad. It is on the East-bound, or track No. 1; 5⅛-inch 80-lb. section; outside rail on a 3-degree curve and down grade of 10 feet per mile. The location is opposite the southeast corner of the West Albany Paint Shop. The ties are yellow pine 7 by 9 inches and 25-inch centres; gravel ballast; the tracks being in good condition. A number of tests of passenger trains were made under the same rail. The experiments made on track No. 2 were directly opposite, the rail being the inside one of the curve. The section was the 5-inch 80-lb. model of 1883; the rails were rolled in 1890 and all straightened on narrow supports in the mills; were heavily gagged and had a wavy surface.

The rails on track No. 1 are much smoother, the supports in the straigthening presses having been made wider apart. On track No. 1 two experiments were made with locomotive No. 596, one at a speed of two miles per hour and one at ten miles per hour. The total weight of the locomotive was 96 tons; the engine 60 tons, with 15,500 lbs. on pony truck and 104,500 lbs. on three pairs of drivers. The tender weighed 72,000 lbs. or 9,000 lbs. per axle. This type of locomotive is the standard for freight service for the road.

It had been recently through the shops for general repairs, the tires of the drivers having been turned the same as when new.

The tender wheels were new cast-iron chilled wheels 33 inches in diameter and unground.

At a speed of two miles per hour the locomotive passed over the rail to which the Stremmatograph was attached, the steam having been shut off a few feet before reaching the instrument.

The record of the molecular compression and elongation of the metal due to the stresses in the base of the rail was very smooth and distinctly delineated.

For the unground tender wheels slight tremors in the rail were distinctly indicated, a fact previously noticed under switching locomotives with the same class of tender wheels running over very light rails in the yard.

The apparent mean stresses for the extreme fibres of five inches in length of the base of the rail computed on a basis of 30,000,000 lbs. for the modulus of elasticity of the steel were as follows.

	For a speed of	
	Two miles per hour	Ten miles per hour
Compression in front of pony truck,	1417 lbs.	1653 lbs.
Tension under pony truck,	7086 "	7558 "
Compression between pony wheel and front driver,	2129 "	4724 "
Tension under front driver,	10629 "	9448 "
Compression between front and middle driver	5433 "	8031 "
Tension under middle driver,	5905 "	4960 "
Compression between middle and rear driver,	4015 "	5673 "
Tension under rear driver,	9376 "	9648 "
Compression between rear driver and first tender wheel,	4015 "	5473 "

For the speed of ten miles per hour the locomotive was working under steam and being accelerated as it passed over the instrument modified the wheel pressures to some extent.

The tremors from the tender wheels were very decided in this run and were felt for the entire length of the rails. The fibre stresses in tension are small for the loads upon the drivers even for an 80-lb. rail, while those in compression are higher than usual for the same weight of rail. The section is 5 ⅛ inches high and the stiffest 80-lb. rail which has been rolled in this country.

There is also another reason for the nearly balanced stresses. The two ties between which the Stremmatograph was attached to the rail were very firm in the ballast, and to the eye did not seem to depress as much as those on either side; therefore, the compression stresses should be higher than on ties all practically depressing alike in the ballast.

It will be exceedingly interesting and important to have the records of stresses under this type of locomotive when drawing one of the trains of fifty-five 60,000-lbs. capacity cars, each carrying 1,000 bushels of grain.

The picture on the screen shows two trains side by side of fifty cars each, the length of one train not quite reaching from New York to Chicago, but each is 2,000 feet long, and 2,640 such trains would fill one continuous track between the two cities. [See Plate XIII.]

In the trials of a number of switching locomotives in the yard, on tracks of not very uniform tie spacing, the locomotives having three pairs of coupled drivers, but without pony truck the front driver usually shows greatest tension on the 65-lb rails.

Under locomotive No. 1, at Grand Central Station, having 125,000 lbs. upon drivers, the instrument between ties of 30-inch centres, having tie plates, the apparent mean stresses were as follows; on 65- and 100-lb, rails respectively:

	65-lb. rail.	100-lb. rail.
Compression in front of driver,	3,071 lbs.	1,181 lbs.
Tension under front driver,	51,964 “	8,031 “
Compression between front and middle driver,	2,124 “	2,834 “
Tension under middle driver,	22,445 “	6,849 “
Compression between middle and rear driver,	2,362 “	2,834 “
Tension under rear driver,	23,856 “	6,142 “

The 65-lb. rails are of recent composition, the elastic limits of the steel being 60,000 lbs., while on the 100-lb. rails it is 65,000 lbs.

In the above table it is interesting to note the great reduction and more uniform fibre stressses in the 100-lb. rails as compared with those in the 65-lb. rails. The 65-lb. rails require from six to eight times as much labor to keep them in surface as the 100-lb. rails in the Grand Central Yard.

The record curves of the stresses of compression and tension of the metal in the rails between and under the wheels consist of a series of very much flattened upper branches for the compression between the wheels with very much sharper lower branches for the tension. [See Plate X., Fig. 1.] A similar record is obtained by having a particular portion of the rail stressed by a moving train as shown by the enlarged records of the Stremmatograph on the screen of two trains. [See Plate X, Fig. 2.]

After the Stremmatograph is attached to the rail a reference line is ruled on the metallic strip and then the scriber point is moved a few thousands of an inch, the instrument started and a line about ¼ of an inch long ruled, which in reality becomes the measure for a median line, and the distance to the reference line measured by the micrometer. When the train is within a rail length of the instrument it is again started; the metallic strip moving at right angles to the rail; the scriber point recording the mean molecular compression and extension of the base of the rail usually for five inches in length.

The upper lines are the records for the 5-inch 80-lb. rail on inside of curve as already described in track No. 2. The rail has a very wavy surface, the stresses being very largely augmented owing to that feature. The locomotive was No, 888, Class I, of the N. Y. C. & H. R. R. R., drawing five Wagner Palace Cars, ; speed 40 miles per hour and being rapidly accellerated. The extension of the metal in the base of the rail due to the the several wheel loads of the locomotive and car can be traced, those of the locomotive being very distinct, while the compression of the metal between the wheels can also be seen.

The rail was the inside one of the curve, track No. 2, in location already described. The rising of the rail in front of the pilot is plainly seen, the stresses of:

Compression being	1,417	lbs.
Tension under front truck wheel	13,070	"
Compression between front and rear truck wheel	3,069	"
Tension under rear truck wheel	12,579	"
Compression between rear truck wheel and front driver.	5,433	"
Tension under front driver	31,415	"

Compression between front and rear driver, ...	2,126	lbs.
Tension under rear driver,..	26,454	"
Compression between rear driver and front tender,.........	2,362	"
Tension under front tender wheels,..........................	12,755	"
Compression between front truck wheels, ...	1,181	"
Tension under rear front tender wheels, ...	13,463	"
Compression between front and rear truck,.................	2,362	"
Tension under rear front truck wheel,.........................	12,991	"
Compression between front and rear wheels,..........	1,889	"
Tension under rear tender wheels,...........	12,755	"
Compression between rear tender wheel and car truck,....	709	"
Tension under front car wheel	14,408	"
Compression between 1st and middle wheel,...............	1,181	"
Tension under middle car wheel,.....	14,172	"
Compression between middle and rear wheel,...............	3,443	"
Tension under rear truck wheel,.................................	13,224	"
Compression in center of space between trucks,.......	00	"

The other wheels of the several trucks of the cars indicate nearly the same stresses.

The record of the other train on the slide is quite similar to the one just described. The tremors and vibrations which are set up by the rapid reversal of the stresses, the slight irregularities in the surface of the wheels are very decided, as the records show.

On the wavy surface of the rail on which these records were taken, the combined static and dynamic effects in producing stresses are about double at 40 miles per hour of the static effects from the same wheel loads. This rate is much higher than has been found upon smooth rails.

The importance of having the rails well finished, as we have compelled the mills to do for some years, is very fully confirmed. The necessity of having smooth wheels, perfectly round is very important, particularly for fast trains.

In a number of records on the same rail, the engines when using steam to accelerate the train, the front driver has shown greater stress than the rear driver except in one instance.

The position of the counter-balance in all of these experiments has been noted by the eye, and up to 35 miles per hour it has not made any noticeable difference in the stresses whether it was up or down on the N. Y. C. & H. R. R. R. locomotives designed for the high-speed trains. This statement must only be taken as applying to the conditions under which these experiments have been made.

For the fast trains the locomotives will be photographed as they pass over the Stremmatograph in the track, and as this must be done nearly on the side it is much more difficult than taking the locomotive on an angle head on, as in the case of those shown of the "Empire State Express."

Stresses in track No. 1, 5⅛-inch 80-pound rail, engine No. 901, with train; speed 20 miles per hour:

Compression in front of pilot,	2,362	lbs.
Tension under front truck wheel,	11,574	"
Compression between truck wheels,	4,724	"
Tension under rear truck wheel,	6,849	"
Compression between truck and front driver,	5,905	"
Tension under front driver,	12,046	"
Compression between front and rear driver,	9,448	"
Tension under rear driver,	14,172	"
Compression between driver and tender wheel,	3,779	"

The rail in this case is the outside one on the curve and in a number of records the stress under the front truck wheel of passenger locomotives have been much higher than in the rear wheel of the same truck, especially on outside rail on a curve.

In static tests the front truck wheel almost invariably shows larger proportional stress than the drivers.

Stresses in 100-pound rail under the "Empire State Express," engine No. 870 and four cars, leaving Grand Central Yard, speed 10 miles per hour.

Compression in front of pilot,	1,322	lbs.
Tension under front truck wheel,	5,947	"
Compression between truck wheels,	1,652	"
Tension under rear truck wheel,	3,304	"
Compression between truck and front driver,	3,139	"
Tension front driver,	8,425	"
Compression between drivers,	2,478	"

Tension rear driver,	6,443	lbs.
Compression between driver and tender truck,	3,965	"
Tension front tender wheel,	4,460	"
Compression between truck wheels,	1,487	"
Tension rear tender wheel front truck	4,460	"
Compression between trucks	2,979	"
Tension front wheel rear truck	4,130	"
Compression between wheels,	1,156	"
Tension rear wheel rear truck,	3,469	"

The rail was the outside one on a 3-degree curve; stone ballast; oak ties with tie plates—24-inch centres.

The marked reduction in the stresses on the 100-lb. rails is very plainly seen.

Testing the Stremmatograph February 14th, 1898; Grand Central Yard at 48th Street, on 100-lb. rail, special brick piers capped with chilled iron supports 30 feet apart. Temperature 44 degrees Fahr. Fairbanks U. S. Standard weights.

The modulus of elasticity taken at 30,000,000 lbs. which for the temperature a number of tests have shown for the same rail to be practically correct.

The Stremmatograph was applied to the base of the rail, and the deflection measured by a micrometer, securely attached to a heavy bridge abutment by which the brick piers were purposely located, and from the centre of the rail 500 lbs. of standard U. S. weights were suspended and the deflection again measured. From the observed deflection the moment of inertia of the rail was recalculated. The section for the test was originally slightly over-weight. The rail has undergone considerable oxidation in two years, reducing the moment of inertia as originally rolled.

For the 500-lb. load the stress in base of the rail computed, 2,747 lbs.

On the Stremmatograph slide, the scriber point was set and a short line ruled, the scriber point was not moved and a second line ruled, but merely displaced by the elongation of the metal, and then the slide slightly moved forward. The slide was then measured under the filar micrometer with the utmost precision and the observed stress computed 2,745 lbs.

Results within a few pounds should be expected between the computed and observed stresses on the brick piers. Close results must be obtained to test the mechanical perfection attained in the construction of the instruments.

The tests mentioned in the paper and many others have all been made upon locomotives and trains in regular service.

TABLE NO I.

GIVING THE GENERAL DIMENSIONS OF THE DIFFERENT RAIL SECTIONS MENTIONED IN THE TESTS OF THE PAPER.

Weight of Section per Yard.	Height of Section in Inches.	Width in Inches of		Thickness of Web. Inches.	Moment of Inertia. Inches.[4]	Neutral Axis Above Base. Inches.	Moment of Resistance. Inches.[3]	Moment of Inertia Vertical Axis Inches.[4]
		Head.	Base.					
65-lb. Old Model.	$4\frac{1}{2}$	$2\frac{1}{2}$	$4\frac{1}{4}$	$\frac{1}{2}$	16.60	2.20	7.546	
80-lb. Dudley, 1883.	5	$2\frac{13}{16}$	$4\frac{13}{16}$	$\frac{1}{2}$	26.00	2.47	10.526	
80-lb. Dudley, 1890.	$5\frac{1}{8}$	$2\frac{21}{32}$	5	$\frac{17}{32}$	28.50	2.50	11.400	4.90
100-lb. Dudley, 1890.	6	3.00	$5\frac{1}{2}$	$\frac{19}{32}$	48.50	2.93	16.553	9.60

NOTE.—In answer to a number of inquiries since reading my paper, regarding the stresses in rails under static loads, I have added as an appendix, a portion of Mr. James E. Howard's description and three tables from his experiments for "Static loads," set forth *in extensio* in the United States Government Report on Tests of Metals and Other Materials for 1895.

This will be a convenience to many who have not access to the above valuable paper.

APPENDIX.

RAILROAD TRACK EXPERIMENTS BY MR. JAMES E. HOWARD.

From Report of the Tests of Metals and other Materials for Industrial Purposes, Made with the U. S. Testing Machine at Watertown Arsenal, Massachusetts. For 1895.

THESE experiments comprise observations on the fibre stresses developed in rails in the track, the depression of the rails, and the slope or inclination of the rails caused by the weight of the different wheels of the locomotive.

The results show some of the phenomena displayed by rails in service under static conditions of loading or when a locomotive passes slowly over the track.

The tests will in a measure supplement laboratory experiments in this class of material, in addition to the aid which they may afford to practical questions pertaining to maintenance of way.

The series were made chiefly on the track of the Pennsylvania Railroad, where exceptional opportunities existed for examining road-bed, embracing a wide variety of conditions of weight of rails and different kinds of ballast, and its behavior under heavy types of freight and passenger locomotives.

The tests were made during the early part of the month of November, 1894, on track in the condition it was found in service.

The experiments on the Boston & Albany Railroad were made, with track on frozen gravel ballast, in the month of February, 1895.

Describing the methods of making the experiments, the fibre stress tests were made by means of a micrometer mounted on the upper side of the outer flange of the base of the rail, at a place midway adjacent ties. The instrument covered a gauged length of 5 inches.

The micrometer was adjusted in position, and then the several wheels of the locomotive were successively brought over the gauged length, or until the same was midway adjacent wheels.

The instrument was read when the locomotive was at each of these positions. It was found practicable to make the micrometre observations without arresting the locomotives in all cases, taking the readings as the locomotives passed slowly over the rail.

In this manner the strains developed were measured, and elongation of the metal showing tensile stress, and a contraction in the gauged length showing compressive stress.

The measured strains, were reduced to stresses per square inch, assuming the modulus of elasticity of the steel to be 30,000,000 lbs. per square inch, and correcting the observed strain in order to obtain the maximum fibre stresses, on the further assumption that the strains were proportional to their distances from the neutral axis of the rail.

TABLE NO. 1.

RAILROAD TRACK EXPERIMENTS—GENERAL DIMENSIONS OF RAILS.

Weight per Yard.	Height.	Width of Base.	Width of Head.	Thickness of Web.	Moment of Inertia I.	Moment of resistance. $R=\frac{I}{n'}$	Distance Neutral Axis to Outside Fibre.	
							Head n	Base n'
Pounds.	Inches.	Inches.	Inches.	Inch.			Inches.	Inches.
60	$4\frac{1}{4}$	$4\frac{1}{4}$	$2\frac{3}{8}$	$\frac{1}{2}$	14.222	6.693	2.125	2.125
70	$4\frac{1}{2}$	$4\frac{1}{2}$	$2\frac{7}{16}$	$\frac{1}{2}$	18.055	8.282	2.32	2.18
85	5	5	$2\frac{9}{16}$	$\frac{17}{32}$	26.374	10.853	2.57	2.43
100	$5\frac{1}{2}$	$5\frac{1}{2}$	$2\frac{11}{16}$	$\frac{9}{16}$	38.957	14.812	2.87	2.63
95	$5\frac{1}{32}$	$5\frac{1}{2}$	3	$\frac{5}{8}$	32.280	13.563	2.65	2.38

TABLE NO. 2.

WEIGHT OF LOCOMOTIVES.

Locomotive.	Total, Pounds.	Engine.		Tender, Pounds.	Weight per wheel.		
		Pilot, Pounds.	Drivers, Pounds.		Wheel.	Pounds.	Tons.
Passenger No. 809, Class Pk.	197.050	39.750	87.300	70.000	Pilot.	9.937	4.968
					Driver, first.	21.750	10.875
					Driver, second.	21.900	10.950
					Tender.	8.750	4.375
Passenger No. 1515, Class T.	222.500	50.300	95.200	77.000	Pilot.	12.575	6.287
					Driver, first.	24.250	12.125
					Driver, second.	23.350	11.675
					Tender.	12.833	6.416
Freight No. 557, Class R.	188.600	11.000	113.800	63.800	Pilot.	5.500	2.750
					Driver, first.	13.250	6.625
					Driver, second.	13.750	6.875
					Driver, third.	15.650	7.825
					Driver, fourth.	14.250	7.125
					Tender.	7.975	3.987
Passenger No. 209, B. & A. R. R.	199.700	40.700	75.000	84.000	Pilot.	10.175	5.087
					Driver, first.	18.750	9.375
					Driver, second.	18.750	9.375
					Tender.	——	——
					First truck.	9.250	4.625
					Second truck.	11.750	5.875

TABLE NO. 3.

MAXIMUM FIBRE STRESSES IN BASE OF RAIL.

Rail Weight per Yard.	Ballast.	Locomotive.	Tensile Fibre Stress per Square Inch.			Compressive fibre stress per square inch.
			Pilot.	Drivers.	Tender.	
Pounds.			Pounds.	Pounds.	Pounds.	Pounds.
60	Gravel.	Pass., No. 809, Class Pk.	6.180	11.670	2.750	1.370
60	"	Frgt., " 557, " R.	3.430	7.550	3.430	.690
60	Stone.	Pass., " 809, " Pk	11.860	19 540	9.770	3.490
60	"	Frgt., " 557, " R.	11.160	16.050	9 770	1 400
70	Cinder.	Pass., " 809, " Pk.	10.730	17.170	10.020	4.290
70	Gravel.	" " " " "	8.970	18.620	8.280	5.520
70	"	Frgt., " 557, " R.	7.590	13.790	6.210	4.830
70	Stone.	Pass., " 809, " Pk.	10.070	14.390	7.910	6 470
70	"	Frgt., " 557, " R.	6.470	11.510	6 470	2.880
70	Bridge.	Pass., " 809, " Pk.	9.450	18.180	10.910	2.180
70	Splice bar.	" " " " "	13.840	22.140	9.230	8.300
85	Cinder.	Pass., " 809, " Pk.	7.160	10 030	5.020	3.580
85	"	" " 1515, " T.	5 730	12 180	7.880	4.300
85	"	Frgt, " 557, " R.	3 580	10.030	5.020	4.300
85	Gravel.	Pass, " 809, " Pk.	10.750	12.180	6 450	4.300
85	"	" " 1515, " T.	9.310	17.120	9.310	5 020
85	"	Frgt., " 557, " R.	7.160	10.030	2.870	7.880
85	Stone.	Pass., " 809, " Pk.	7 160	10.750	4.300	4.300
85	"	Frgt., " 557, " R.	4.300	10.030	5.020	3.580
100	Stone.	Pass., " 809, " Pk.	6.320	9 840	5.620	4.220
100	Stone—tie removed.	" " " " "	10.540	18.970	8 430	2.110
100	Stone.	Frgt., " 557, " R.	3 510	8.430	4 220	2.810
95	Frozen grav. rail No. 1.	Pass., " 209, Bra. R R.	6 870	9.920	6.870	3.050
95	Frozen grav. rail No. 2.	" " " " "	7 630	11.450	6.870	a 7.630

"a" Taken at different point on the rail.

PLATE X.

EXPLANATIONS OF PLATE X.

FIG. 1.—Representation of the continuous curve showing how the metal of the rail is stressed under the wheel loads of a train.

FIG. 2.—Wheel loads and wheel base of Boston and Albany Passenger Locomotive, No. 209, on 95-lb. rails; showing deflection of rail and depression of the ties, ballast and road-bed under the wheel loads.

FIG. 3.—Stremmatograph records, enlarged 2½ times. The first made under fast trains, the tremors and vibrations in the rails being very decided. The records on the bronze plates are more distinct than in the reproduction. The upper record was from locomotive No. 888 and 5 Wagner Palace cars; the lower record was from locomotive No. 889 and 7 cars.

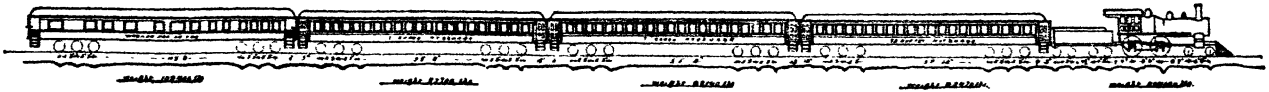


FIG. 1.

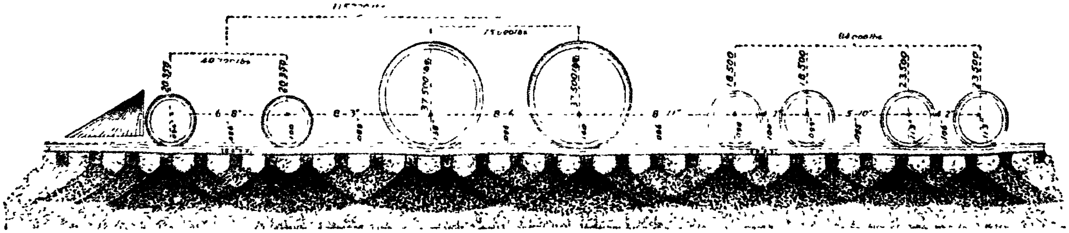


FIG. 2.

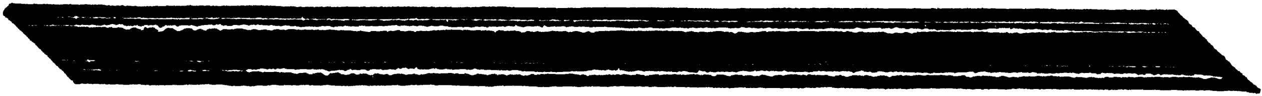


FIG. 3.

PLATE XI.

PLATE XI.

FIG. 1.—Stremmatograph attached to base of rail to obtain record of the stresses of locomotive No. 596 on Track No. 1, 5⅛-inch 80-lb. rails.

FIG. 2.—Locomotive "DeWitt Clinton" and train of the Mohawk and Hudson R. R. Co., 1831. The first American constructed locomotive and train. The inception of the New York Central and Hudson River Railroad. The progress of 60 years was demonstrated by the installation of the "Empire State Express" in 1891, the "fastest long distance train in the World."

FIG. 1.

FIG. 2.

PLATE XII.

PLATE XII.

Fig. 1.—"Empire State Express" running 60 miles per hour on 65-lb. rails. Locomotive No. 862, Nov., 1891.

Fig. 2—"Empire State Express" running 60 miles per hour on 80-lb. rails. Locomotive No. 903.

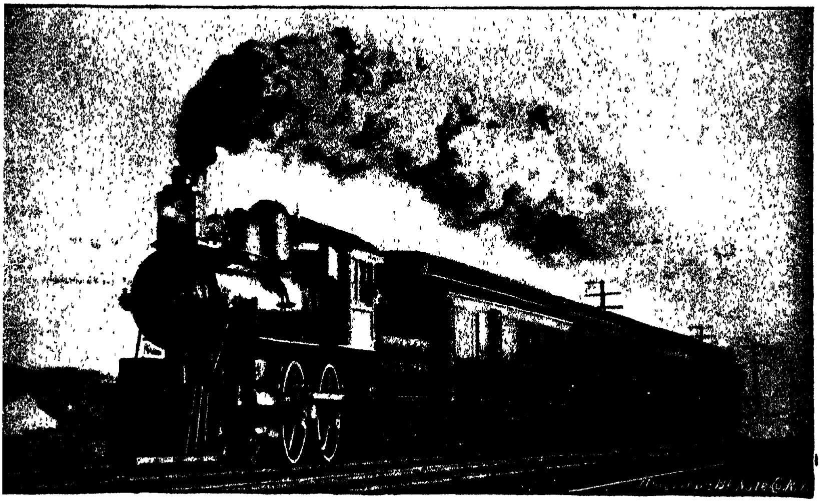


FIG. 1.

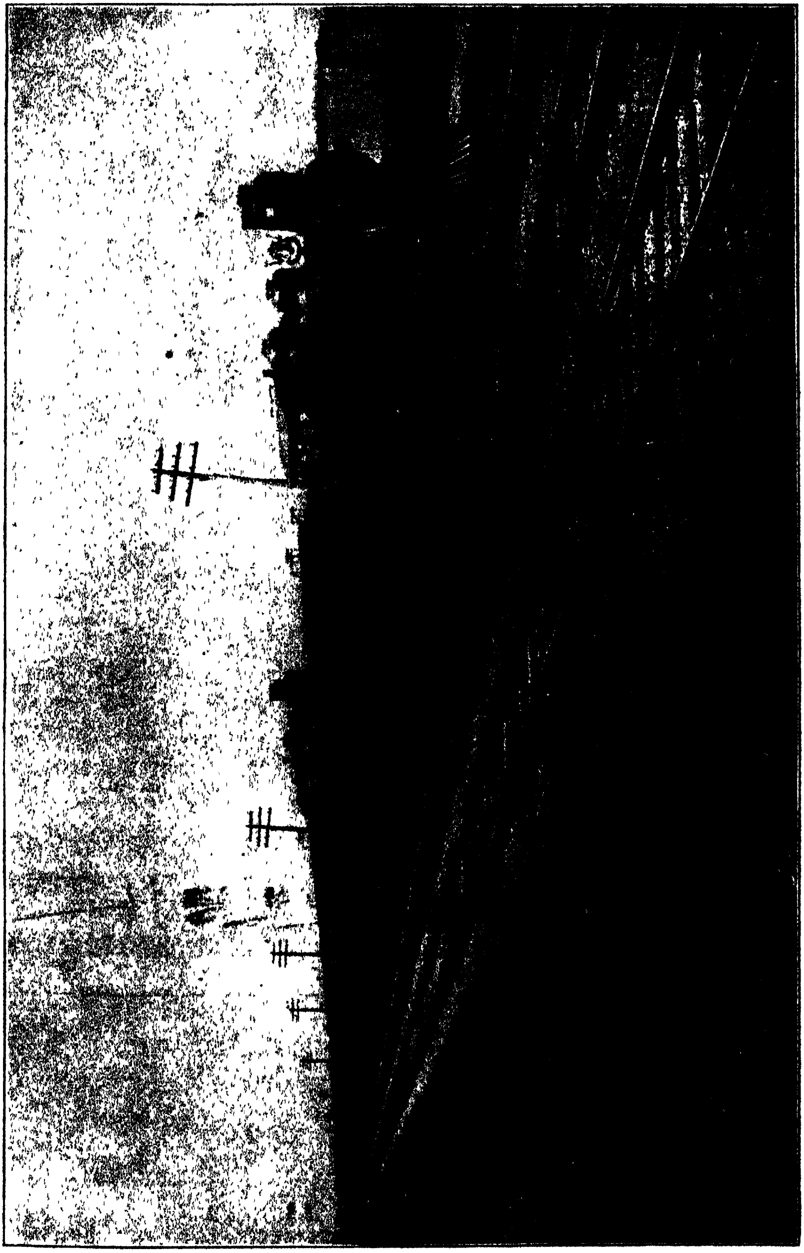
FIG. 2.

PLATE XIII.

PLATE XIII.

N. Y. C. and H. R. R. R. freight trains, fifty cars each. Karmer, N. Y. 1893.

PLATE XIII.



[ANNALS N. Y. ACAD. SCI., XI, No. 7, pp. 117 to 126, May 17, 1898.]

DESCRIPTIONS OF DEVONIAN CRINOIDS AND BLASTOIDS FROM MILWAUKEE, WISCONSIN.

STUART WELLER.

(Read February 21, 1898.)

[PLATE XIV.]

THE Devonian strata at Milwaukee, Wisconsin, consist of two distinct formations. The lower of these is the hydraulic limestone which is quarried for the manufacture of cement. In this limestone the fossils generally occur as internal casts and external impressions, though some of the smaller forms are sometimes replaced by pyrite. Lying above the limestone is a bed of soft, blue, easily disintegrated shale, containing some thin bands of harder limestone. In this shale the fossils are abundant and often occur perfectly preserved.

The faunas of the two horizons are markedly different, scarcely a species which occurs in the limestone being present in the shale. In the limestone fauna there are many species identical with those in the Hamilton group as typically developed in New York, while in the shale the species are apparently more nearly allied to species in the Iowan Devonian faunas.

The crinoids and blastoids here described are all from the shale, and while the crinoids are quite different from other members of the genus to which they belong, they are to be compared with species which have been described from Iowa and Missouri rather than with any of the more eastern species.

With the exception of *Pentremitidea filosa* (?) which was collected by Mr. A. W. Slocom, all the specimens were collected by Mr. E. E. Teller, of Milwaukee, and are now in his collection.

Melocrinus nodosus Hall.

(Pl. XIV. Fig. 6.)

1861. *Melocrinites nodosus* Hall, Rep. Prog. Geol. Surv. Wis., p. 19.

1895. *Melocrinus nodosus* Whitfield, Mem. Am. Mus. Nat. Hist., vol. I, p. 48, Pl. V, fig. 14.

Calyx pyriform, truncate at the base, sides straight or slightly convex from the tops of the basals to the arm openings ; cross-section, as seen from above, exclusive of the nodes, obscurely subpentagonal, greatest diameter at the arm bases. The plates of the dorsal cup ornamented with conspicuous nodes.

Basals four, projecting laterally into more or less prominent nodes, columnar facet large, often somewhat depressed between the nodes of the plates. Radials large, heptagonal and hexagonal, strongly nodose. First costals hexagonal, smaller than the radials, strongly nodose; second costals pentagonal or heptagonal, smaller than the first and less strongly nodose. Distichals smaller than the last costals, higher than wide, free beyond the first pair. First interdistichals hexagonal, as large as the first costals and bearing similar nodes, followed by two smaller nodose plates in the second row, one of which often bears a larger node than the other ; in the third row there are two or three smaller plates and above these numerous small plates which lead up to those of the vault. The posterior interradius is not differentiated from the other four.

Ventral disk depressed convex or nearly flat, composed of small polygonal nodose plates of nearly equal size ; marked by more or less prominent rounded ambulacral ridges which extend from the arm bases towards the center; and surmounted by the base of a subcentral proboscis whose height cannot be determined.

Remarks. This species, although described, but not illustrated, by Hall in 1861, is not recognized by Wachsmuth and Springer in their recent monograph, it being passed over with the remark that it was described from imperfect casts.[1] The specimens used by Hall in his description are recorded as coming from the drift about Milwaukee and also from Iowa City, Iowa. It is possible that Hall included in his species all the nodose forms from Milwaukee, but from a study of a considerable number of specimens I am led to recognize two good species. Whitfield's illustration of the species is drawn from the largest of Hall's type specimens, and, except in its larger size, differs in no essential respects from the one here illustrated.

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[1] The North American Crinoidea Camerata. By Chas. Wachsmuth and Frank Springer. Vol. I, p. 294.

Although two species and one named variety, of these nodose forms are recognized in the present paper, it is possible that some would prefer to include them all in a single variable species. All the specimens, however, which have come under my observation can be placed without hesitation in one of the two recognized species, *M. nodosus* and *M. subglobosus*, but it is more difficult to separate the variety *spinosus* from the typical specimens of *M. nodosus*. The distinguishing differences between the two species will be pointed out in connection with the description of *M. subglobosus*.

With the exception of the associated *M. subglobosus*, *Melocrinus nodosus* is quite distinct from any other species of the genus. It need only be compared with *M. calvini*[1] from the Devonian of Johnson Co., Ia., and *M. gregeri*[2] from the Devonian of Callaway Co., Mo., and from both of these species it differs in its much more strongly nodose plates.

Melocrinus nodosus var. **spinosus** n. var.

(Pl. XIV. Fig. 2.)

This variety differs from the typical form of the species in its higher and narrower calyx, and in its more pointed spine-like nodes.

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[1] Wachsmuth and Springer, N. Am. Crim. Cam., Vol. I, p. 300, Pl. XXII, fig. 6.

[2] Rowley, Am. Geol., Vol. XII, Nov. 1893, p. 303, Pl. XVI, fig. 1.

Melocrinus subglobosus n. sp.

(Pl. XIV. Fig. 1.)

Calyx sub-globular, sides convex from the tops of the basals to the arm openings. Cross section, as seen from above exclusive of the nodes, circular, greatest diameter at about the top of the first costals. The plates of the dorsal cup ornamented with remarkably large nodes, the radials, first costals and first and second interbrachials often bearing nodes whose diameter is nearly equal to the width of the plates. The larger nodes rise abruptly from the general surface of the plates, with subparallel sides and with an elevation equal to their diameter.

Basals four, projecting laterally into more or less prominent nodes, columnar facet large, often somewhat depressed between the nodes of the plates. Radials large, heptagonal and hexagonal, strongly nodose. First costals hexagonal, smaller than the radials, strongly nodose; second costals pentagonal or heptagonal, smaller than the first, bearing a much smaller and lower node. Distichals smaller than the last costals, the second pair free and attached to the first by a conspicuous sub-circular facet with numerous fine radiating ridges. First interbrachials hexagonal in the four regular interradial areas, as large as the first costals, and bearing similar nodes, followed by two smaller plates in the second row, one of which often bears a conspicuous node similar to those of the lower plates and the other with a much lower and smaller inconspicuous node similar to those upon the second costals; above the second row the interradial spaces are filled with numerous smaller plates which lead up to those of the dome. The posterior interradius with a heptagonal nodose anal plate in the first row, similar, except in outline, to the first regular interbrachials, followed by three plates in the second row.

Ventral disk subhemispherical, composed of small, polygonal, nodose plates of nearly equal size, and surmounted by the base of a subcentral proboscis whose height cannot be determined.

Remarks. M. subglobosus is most nearly allied to the associated species *M. nodosus.* It differs from this species: 1. In its subglobose form, with the vault subhemispherical rather than depressed convex or nearly flat. 2. In its more strongly nodose plates, the nodes in this species being nearly as thick at their bases as the width of the plate of which they are a part, with the sides of the nodes subparallel or even in some cases diverging outward, making the node somewhat club-shaped, being thicker towards its extremity than at its base, while in *M. nodosus* the sides of the nodes always converge outwards. 3. In the presence of three plates rather than two in the second row of interbrachials on the posterior side.

Melocrinus milwaukensis n. sp.

(Pl. XIV. Fig. 7.)

Calyx pyriform, truncated at the base, sides slightly convex from the tops of the basals to the arm openings. Cross-section, as seen from above, obscurely pentagonal. Greatest diameter at the arm bases. All the plates of the dorsal cup convex or ornamented with low, broad, central nodes.

Basals four, moderately nodose, not projecting far beyond the column. Radials large, heptagonal and hexagonal. First costals hexagonal, smaller than the radials, second costals pentagonal or heptagonal, smaller than the first. Distichals much smaller than the last costals, the second or third pair becoming free. First interbrachials in the four regular interradial areas, hexagonal, as large as the first costals, followed by two smaller plates in the second and three still smaller ones in third row, these being followed by small plates which lead up to the interradial plates of the vault. In the posterior interradius the first or anal plate is similar in size to the first interbrachials of the other sides, but is heptagonal in form, being followed by three plates in the second row.

Ventral disk depressed convex or nearly flat, composed of small polygonal nodose plates of nearly equal size; marked by more or less prominent ambulacral ridges extending from the arm openings towards the center; and surmounted by a subcentral proboscis whose height cannot be determined.

Remarks. This species with its associated variety differs from the two preceding species in having, simply, more or less strongly convex plates in the dorsal cup, instead of the great nodose plates of those species. Both the typical form and the variety agree with *M. subglobosus* in the arrangement of the plates in the posterior interradius, but in general form the species more closely resembles *M. nodosus* and its variety *spinosus.*

Melocrinus milwaukensis var. **rotundus** n. var.

(Pl. XIV. Fig. 4.)

This variety differs from the typical form in being shorter, with more convex plates, in the basals being more strongly nodose, and in the more convex subhemispherical vault.

Pentremitidea filosa Whiteaves (?)

(Pl. XIV. Fig. 3.)

1889. *Pentremitidea filosa* Whiteaves, Cont. Can. Pal., Vol. I, p. 104, Pl. 14, Figs. 1–1b.

Body small, proportion of width to height as 3 to 5. Maximum breadth at or near the base of the radial sinus. Lateral outline subovate, but conical at the base and truncated at the apex; cross section at part of maximum width, decagonal, the sides of the decagon represented by the ambulacral areas, short and concave, the other sides nearly straight or slightly concave.

Basal plates three, two pentagonal and larger than the third, which is quadrangular; about one-fourth as high as the radials. Basal cup strongly trihedral, about as high as wide, and reaching more than half way to the bases of the radial sinuses. Radial plates lanceolate in outline, nearly three times as high as wide; the bodies or undivided portions spread outward more rapidly than the basals, and occupy one-fourth of the total length of the plates. The apices of each of the two adjacent radials are united to form an acute point which projects a little above the summit. Radial sinuses deep, the sides elevated and forming sharp edges, the portion bounding the base of the sinus more highly elevated into a conspicuous node-like projection. Deltoid plates, with the exception of the posterior one, apical, not visible in a side view. Posterior deltoid small, rhomboidal, not well preserved in the specimen.

Ambulacra linear, narrow, narrowly rounded at the base and about one-half as wide at that point as at the summit. Surface transversely convex, forming a longitudinal depression along each side, the central portion raised not quite to the general level of the radials. The food groove in the center of each ambulacrum deepens and broadens near the summit.

Spiracles five, rather large, the posterior one confluent with the anal opening. The remaining characters of the summit not well preserved.

Surface of the radials ornamented with fine concentric lines which are only visible with a lens.

Remarks. The species here figured and described is with some hesitation identified with Whiteaves *P. filosa.* It differs from that species in its greater proportionate height, the proportions between the width and height in Whiteaves' figure being 3 to 4, while in the Milwaukee species it is 3 to 5 ; in the higher and more slender basal cup, and in its more conspicuous node-like projections of the radials at the basal margin of the sinus. So far as the Milwaukee specimens have been observed, they are always smaller than Whiteaves' figures.

Pentremitidea milwaukensis n. sp.

(Pl. XIV. Fig. 5.)

Body of medium size, lateral outline subovate, maximum breadth a little below the middle of the radial sinuses. Cross-section at the point of maximum width decagonal, the sides of the decagon represented by the ambulacral areas, short and concave, the other sides longer, nearly straight or slightly concave.

Basal plates three, two pentagonal and larger than the third, which is quadrangular, less than one fifth as high as the radials. Basal cup trihedral, wider than high. Radials lanceolate in outline, a little more than twice as high as wide ; the bodies or undivided portions spread outward in a nearly horizontal position, occupying about one fifth of the total length of the plates. The apices of each of the two adjacent radials are united to form an acute point which projects a little above the summit. Radial sinuses deep, the sides subparallel, elevated so as to form sharp edges, the portion bounding the base of the sinus more highly elevated than at other points. Deltoid plates apical, not visible in a side view, except on the posterior side, where there is a small rhomboidal plate.

Ambulacra linear, narrowly rounded at the base, and but little wider at the summit than at the base. Surface transversely convex, forming a longitudinal depression along each side, the central portion not raised to the general level of the radials. The food groove along the median line of each ambulacrum deepens and widens near the summit.

Spiracles rather large, the posterior one confluent with the arms.

Surface of the radial plates ornamented with prominent raised concentric ridges which converge downwards towards the lateral sutures.

Remarks. This species is in many respects similar to the last, but differs in its larger size and in its proportionally broader radials and shorter base, giving to the body a fuller appearance. The rounded base of the radial sinus and ambulacra is broader and more obtuse in this species than in the last, and the sides of the ambulacra are more nearly parallel. The concentric ornamentation of sharply elevated ridges upon the radials, is much more conspicuous than in the last species, it being always easily recognized without the aid of a lens.

In the specimen figured the base is not preserved, the outline indicated being taken from another specimen.

THE UNIVERSITY OF CHICAGO,
January 18, 1898.

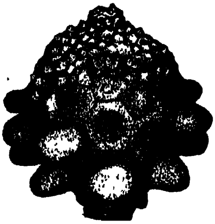
PLATE XIV.

EXPLANATION OF PLATE XIV.

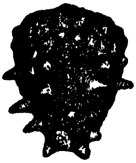
FIG. 1. *Melocrinus subglobosus* n. sp. p. 119.
FIG. 2. *Melocrinus nodosus* var. *spinosus* n. var. p. 119.
FIG. 3. *Pentremitidea filosa* Whiteaves (?). p. 122.
FIG. 4. *Melocrinus milwaukensis* var. *rotundus* n. var. p. 122.
FIG. 5. *Pentremitidea milwaukensis* n. sp. p. 123.
FIG. 6. *Melocrinus nodosus* Hall. p. 118.
FIG. 7. *Melocrinus milwaukensis* n. sp. p. 121.

Figure 7 of this species represents the basal plates as somewhat larger than they are in the specimen.

PLATE XIV.



1



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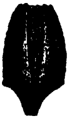

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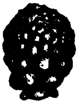

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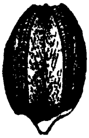

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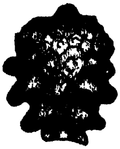

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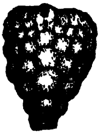

7

Stuart Weller, del.

[ANNALS N. Y. ACAD. SCI., XI, No. 8. pp. 127–149, May 17, 1898.]

THE EPARTERIAL BRONCHIAL SYSTEM OF THE MAMMALIA.

GEO. S. HUNTINGTON.

(Read February 14, 1898)

[PLATES XV–XXVIII.]

INTRODUCTION.

DURING the past five years I have devoted much time to the examination of the mammalian lung in reference to the structure of the bronchial system and the distribution of the pulmonary vascular supply. In presenting, as a preliminary communication, some of our more important results to the Section at this meeting, I may state that the research is by no means completed, although it comprises the detailed examination of over two hundred lungs from all orders and many families of the mammalia. Some of the facts established appear to me so conclusive that I do not hesitate to direct your attention to the same, especially because they render my interpretation of the mammalian type of bronchial distribution and pulmonary vascular supply different from the one presented by Ch. Aeby in his valuable monograph "Der Bronchialbaum der Säugethiere und des Menschen." Inasmuch as Professor Aeby's views have been adopted, almost without exception, by the authors of current anatomical text-books and incorporated more or less extensively in these volumes, the matter appears to me one of more than common interest and importance.

The preparations upon which the conclusions stated in this paper are based were obtained almost invariably by corrosion of the injected bronchial system and pulmonary artery, the only methods which I believe can be relied upon to give absolute and satisfactory results.

I have appended to this paper a nearly complete bibliographical list of articles on the subject which have appeared since the publication of Professor Aeby's book in 1880.

Before proceeding to details, I may briefly recapitulate the main facts and conclusions which Professor Aeby's work contains on the mammalian lung.

1. Aeby recognizes in each lung a main or "stem"-bronchus which can be followed caudad and dorsad throughout the entire lung, diminishing in size gradually by giving off lateral branches, capable of being separated into a dorsal and ventral set. Aeby defines this as the monopodic type of division.

2. The pulmonary artery follows the same general plan of distribution, the main trunk of each side crossing the bronchus ventro-dorsad and continuing caudad on the dorsal aspect of the stem-bronchus, between the ventral and dorsal lateral branches, which are separated from each other by the vessel.

3. In the human lung and in the lungs of most mammalia the lateral branches on the left side are all given off from the stem-bronchus caudad of the point of intersection of the same with the artery. They constitute, therefore, a group of "Hyparterial bronchi." On the right side in man and in most mammalia a bronchus is given off from the stem-bronchus cephalad of its intersection with the pulmonary artery. Aeby distinguishes this bronchus, which in man supplies the upper lobe of the right lung, as the "Eparterial" bronchus.

4. Inasmuch as the upper lobe of the left and the middle lobe of the right lung is supplied by the first "ventral hyparterial bronchus," Aeby considers them homologous, regarding the "eparterial" bronchus and its resulting lobe (upper right) as an entirely new structure confined to the right lung, and morphologically not represented on the left side.

5. While this arrangement obtains in man and most mammalia, Aeby's researches revealed the fact that certain forms are aberrant in reference to the bronchial and pulmonary vascular distribution.

Aeby classifies the various types determined by himself as follows, the list being completed by the forms examined subsequently by M. Weber:

I. Bronchial Tree with bilateral Eparterial Bronchus.
  a. Eparterial Bronchus on both sides bronchial in derivation: *Bradypus*, *Equus*, *Elephas*, *Phoca*.
  b. Eparterial Bronchus bronchial in derivation on left side, tracheal on right: *Phocæna communis*, *Delphinus delphis*, *Auchenia*.

II. Bronchial tree with Eparterial Bronchus only on right side.
  a. Eparterial Bronchus bronchial in derivation: *Monotremata*, *Marsupalia*, *Edentata* (except *Bradypus*), *Rodentia* (except *Hystrix*), *Carnivora*, *Insectivora*, *Chiroptera*, *Prosimiæ*, *Primates*.
  b. Eparterial Bronchus tracheal in derivation: *Artiodactyla* (except *Camelus* and *Auchenia*), many *Cetaceans* (*Epiodon australe*, *Hyperoodon rostratus*, *Balænoptera rostrata* and *sibbaldii*).

III. Bronchial tree without Eparterial Bronchus. Bilateral hyparterial system: *Hystrix cristata*, *Balæna mysticetus* and *antipodum*.

IV. Bronchial tree with triple division of Trachea into three unequal Bronchi: *Pontoporia blainvillei*. (Isolated type—not found in any other mammal.)

The above postulates comprise, I believe, the main results of Aeby's research as far as they concern the subject of the present communication. They have been, as already stated, almost universally adopted and have found place, as recognized anatomical facts, in the majority of current text-books on human and comparative anatomy.

Among the subsequent contributions to the morphology of the bronchial tree one deserves special mention, on account of its importance and because it appears to me that it has not received the attention which it deserves. Albert Narath, in 1892, presented a communication to the "Anatomische Gesellschaft," entitled "Vergleichende Anatomie des Bronchialbaumes," published in the "Verhandlungen d. Anat. Gesell. VI. Versammlung, 1892." In this paper Narath controverts a number of Aeby's conclusions very forcibly.

Narath establishes the following propositions, based on extensive comparative and human material:

1. The pulmonary artery in the greater part of its course is placed *laterad* of the stem-bronchus, and does not *cross* the same in Aeby's sense.
2. The pulmonary artery does not influence the structure of the bronchial tree.
3. There is no fundamental difference between the "eparterial" and "hyparterial" bronchi of Aeby.
4. The "eparterial" bronchus is a dorsal (first dorsal) branch, probably originally a lateral branch of the first ventral bronchus shifted upwards on the stem-bronchus.
5. The right eparterial bronchus (when alone present as in man) is represented by an "apical" bronchus on the left side, derived as a lateral branch from the first ventral bronchus.

These important conclusions of Narath will be subsequently again referred to in comparing them with the results obtained by our investigations.

If we now, carefully and without prejudice, examine a large number of corrosion preparations of mammalian lungs, in which the bronchial system and pulmonary artery have been injected, the following facts will reveal themselves:

1. A unity of ground plan can be discerned in all, modified in various forms by:
    a. Migration of one or more secondary bronchi cephalad on the main bronchus, or even on the trachea.
    b. Corresponding changes in the branching of the pulmonary artery.
    c. The appearance, in many forms, of a right accessory (cardiac or azygos) bronchus.
2. If asymmetry exists the right lung is in general the one favored by the greater development and increased calibre and number of the bronchial branches. This physiological precedence of the right over the left lung is characterized by the following facts:

- *a.* The "eparterial" bronchus, if unilateral, is always on the right side.
- *b.* The "cardiac" bronchus is always on the right side.

EXAMINATION OF TYPES.

We may profitably begin our consideration of the mammalian bronchial tree by examining seriatim a number of selected types, subsequently comparing the members of the entire series, in their probable phylogenetic relation to each other, and draw our general conclusions from such comparison.

For reasons, which will be stated later, and which induce us to regard the form as the representative of the primitive mammalian lung, we begin with the type described by Aeby as "Bronchial Tree without Eparterial Bronchus," the complete bilateral hyparterial type.

I. Hystrix cristata—European Porcupine.

Corrosion of bronchial system and pulmonary artery. Columbia University Museum, No. 413. Pl. XV.

The caudal end of the trachea enlarges to a capacious pentagonal bulla or lacuna, slightly compressed dorso-ventrally.

The bronchi, hyparterial in their derivation on both sides and perfectly symmetrical, arise from the tracheal bulla as two main trunks, cephalic and caudal (Pl. XV, *A*, *A*, *B*, *B*). Each trunk divides, in a nearly dichotomous manner, into two nearly equal secondary branches (Pl. XV, *A′*, *A″*, *B′*, *B″*), which in turn give off, by monopodic division, tertiary branches.

1. Cephalic Trunk (Pl. XV, *A*, *A*).
   - *a.* Apical Branch (*A′*) passes to the anterior portion of each lung.
   - *b.* Lateral Branch (*A″*) supplies the central (middle) portion of each lung.
2. Caudal Trunk (Pl. XV, *B*, *B*). Both medial and lateral secondary branches (*B′* and *B″*) ramify in the posterior portion of the lung.

II. a. Taxidea Americana—American Badger.

First specimen; juvenile animal.

Corrosion of bronchial system and pulmonary artery. Columbia University Museum, No. 1254. Pl. XVI.

The tracheal lacuna is large, bullous, rounded, projecting caudad with a blunt rounded terminal cupola between the caudal bronchial trunks.

The primary trunks of right and left side, two in number (Pl. XVI, *A*, *A*, *B*, *B*), arise directly from the expanded tracheal bud. They are, however, compared with those of *Hystrix*, no longer quite symmetrical.

1. LEFT LUNG.

a. Cephalic Trunk (*A*).

Large, directed cephalo-laterad, distributing by monopodic division, secondary branches cephalad and caudad.

b. Caudal Trunk (*B*).

A short wide stem, directed caudo-laterad. It divides, dichotomously, into two main secondary branches, a medial and a lateral (*B'*, *B''*), each of which again divides in a nearly dichotomous manner, the main secondary and the resulting tertiary branches giving off monopodic lateral twigs. (Mixed dichotomous and monopodic type of division.)

2. RIGHT LUNG.

a. Cephalic Trunk (*A*).

A short wide stem, directed cephalo-laterad, divides into secondary branches as follows:

α. A slightly smaller apical branch directed cephalo-laterad (*A'*).

β. A somewhat larger lateral branch, directed latero-caudad (Pl. XVI, *A''*). Each secondary branch gives off monopodic tertiary branches.

b. Caudal Trunk. (*B*).

Very short, sessile, directed caudo-laterad. Divides almost immediately into two secondary branches of nearly equal size (*B'*, *B''*), the lateral branch (*B'*) being slightly the larger. Each of these, as on the left side, gives off two terminal tertiary branches, which are studded with monopodic lateral twigs.

The two tertiary branches resulting from the division of the medial secondary bronchus (*B''*) are characterized by obtaining their arterial supply through a large trunk passing from the main pulmonary artery ventro-caudad between the cephalic and caudal trunks (angle between *A* and *B*), and inclining mesad across the secondary lateral branch of the caudal trunk (*B'*) to reach the terminal divisions of the medial branch of the same trunk (*B''*). The topography of this arterial vessel (Pl. XVI, *C*) is entirely characteristic of the usual blood-supply to the infracardiac, or Azygos lobe in other Mammalia (*cf. infra*).

II b. **Taxidea Americana—American Badger.**

Second specimen, large full-grown male. Corrosion preparation of bronchial system and pulmonary artery. Columbia University Museum, No. 1255. Pl. XVII.

Presents the same characters as the first specimen as regards the tracheal bulla, and the derivation of the cephalic and caudal primary trunks (*A* and *B*). The tertiary branches are more fully developed and give off more numerous and larger monopodic lateral twigs.

The main interest, compared with the first specimen, centers around the cephalic trunk (*A*) of the left lung. The trunk is only slightly smaller than the one of the right side. It divides into a large cephalic or apical branch (*A'*) and a very much smaller lateral branch (*A''*), while on the right side the primary cephalic trunk *A* divides into two nearly equal secondary branches (*A'* and *A''*). We may, therefore, assume that the large left cephalic bronchus of the younger specimen (Pl. XVI, *A*) corresponds in the main to *A'* of the older animal, and that one of the proximal lateral branches develops into branch *A''* of the adult.

The asymmetry of the right lung compared with the left is well marked. The main secondary branches (*A'*, *A''*) derived from the right cephalic trunk (*A*) exhibit a tendency toward complete separation and individual independence. The arterial supply of the medial secondary branch (B'') derived from the right caudal trunk (B) presents the same typographical peculiarity found in the younger specimen.

GENERAL CONSIDERATION OF THE "BILATERAL HYPARTERIAL TYPE," AS SHOWN IN THE PRECEDING PREPARATIONS.

1. *Taxidea americana* is a new form, presenting the bilateral hyparterial type, now described in detail for the first time, although I called attention to the peculiarities of the pulmonary structure of this animal in the "Cartwright Lectures," delivered in April 1896.

2. Comparison with the remaining mammalian forms leads me to regard the bilateral hyparterial type as the *primitive condition* of the mammalian lung, whereas Aeby (1) and Wiedersheim (Vergl. Anat. Lehrb., p. 262–266) consider it a complete reduction form, resulting from the bilateral suppression of the "eparterial" bronchus. The reasons for the opinion expressed are as follows:

a. The tracheal lacuna or bulla corresponds to the condition presented by the tracheal bud during the early stages of pulmonary development in mammalian embryos.[1]

b. During the early developmental stages the pulmonary artery passes caudad on each side of the tracheal stalk to the point of division. The subsequent descent of the heart turns the pulmonary trunk ventrad and caudad into the position which it later occupies in relation to the tracheal bifurcation. Hence the original position of the tracheal buds is "hyparterial.

The appearance, therefore, both of the bronchial system and of the pulmonary artery in *Hystrix* and *Taxidea* represents a persistent embryonal type.

3. We may add that this type appears as an exceedingly exceptional one in the mammalian series. In obedience to an

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[1] Robinson, Arthur, "Observations on the earlier stages in the development of the Lungs of Rats and Mice," Jour. Anat. and Phys., Vol. xxiii, Pt. ii, January 1889, p. 224.

almost universal law, extension of the bronchial system by migration cephalad of some of the secondary branches brings about asymmetry of the tree and a changed relation of the cephalic primary bronchus to the pulmonary artery.

The only forms in which the bilateral hyparterial type is known to exist are:

Hystrix cristata (Aeby),
Balæna mysticetus and *antipodum* (M. Weber),
Taxidea americana (Huntington).

Turning now to the conditions presented by the remaining mammalia, I have selected the following series of typical modifications, and will present them in the order in which the subsequent general phylogenetic comparison will be made.

III. Canis familiaris—Dog, ♀.

Corrosion preparation of bronchial system and pulmonary artery. Columbia University Museum, No. 1256. Pl. XVIII.

The type presented is the one followed by the vast majority of mammalia, and is defined by Aeby as "bronchial tree with eparterial bronchus only on the right side, bronchial in derivation." There is a well-developed cardiac bronchus (*C*) supplying the Azygos lobe.

Even a cursory examination of this preparation reveals the fact that, with the exception of the cardiac bronchus, a strict equivalence of bronchial elements exists on the right and left sides, but that their relation to the primary bronchus and the main trunk of the pulmonary artery differs on the two sides.

a. *Left Side.*

The first bronchus is a short, thick stem, hyparterial in position (*A*), which divides into an apical and a lateral branch (*A'*, *A''*). Compared with *Hystrix* and *Taxidea*, it is not difficult to recognize in the former the cephalic trunk (*A*) and in the latter the two secondary branches (*A'* and *A''*). The caudal portion of the bronchial tree below the origin of *A* appears as the "stem-bronchus" of Aeby, from which the remaining secondary branches are derived. Compared with *Hystrix* and *Taxidea*, we recognize the element B, between the origin of the first hyparterial trunk A, and the origin of the lateral branch B', corresponding to the caudal trunk B of *Hystrix* and *Taxidea.* The lateral branch B' corresponds to the same element in the bronchial system of *Taxidea* and *Hystrix.*

The continuation caudad of the stem-bronchus occupies the site of the secondary caudal branch B'' in *Hystrix* and *Taxidea*, and, like this branch, divides into two nearly equal segments, a medial and a lateral, each of which gives off monopodic dorso-medial and ventro-lateral twigs.

The general comparison, therefore, of the left bronchial system of *Canis* with the bilateral hyparterial type of *Hystrix* and *Taxidea* results as follows :

Hystrix and Taxidea.		*Canis.*
A	=	A
A'	=	A'
A''	=	A''
B	=	B
B'	=	B'
B''	=	B''

Aeby's "stem-bronchus" appears as the result of the following rearrangement and further development :

1. The proximal part, between the bifurcation and the origin of the cephalic trunk A ("primary left bronchus") results from the segmentation and division of the tracheal bulla.

2. The second segment of the stem-bronchus is formed by the element B (caudal trunk) between the origin of A and the derivation of B'.

3. The third segment is continued caudad as the representative of B'' (medial secondary caudal branch), while the lateral branch (B') appears as its secondary derivative. Hence we may regard the typical "stem-bronchus" as it appears in the majority of mammalia in the following light :

"Stem-bronchus" = segmented tracheal bulla + B + B'', medial division.

A and its two secondary divisions A' and A'', B', as well as the lateral division of *B''*, appear as lateral (secondary) branches derived from the parent-stem. We have the dichotomous type of division of the primitive form replaced by the monopodic origin of lateral branches from a main parent or stem-bronchus, which condition characterizes the lung of the higher mammalia.

b. *Right Side.*

The first fact noticed is the complete separation of the branches *A* and *A'* and the consequent elimination of the primary cephalic trunk *A*. *A'* has migrated slightly dorsad and cephalad, so as to arise from the stem-bronchus near the bifurcation. *A''* has shifted ventrad and slightly caudad on the stem-bronchus. The interval thus opened between them by the elimination of the trunk *A* is utilized by the right pulmonary artery to gain the dorso-lateral aspect of the stem-bronchus.

In general there can be no question as to the morphological equivalence, regarding direction, size and lung area supplied, of the branches *A'* and *A''* on right and left sides. The same is true regarding the corresponding branches of the pulmonary artery. To be noted is the early derivation of the arterial trunk accompanying *A'* on the right side; also the somewhat more pronounced independent character of *A'*, revealed by the greater number and size of its lateral secondary and tertiary derivatives, all facts accentuating the physiological importance which the apical portion of the right lung has assumed.

The caudal segment follows in the main the type presented by the left side. We recognize the same character and derivation of the stem-bronchus.

A new element, not represented on the left side, appears as the cardiac bronchus (*C*), derived from the stem-bronchus (segment *B*) caudad and mesad to the separate origin of *A''*. Comparison with the bronchial tree of *Taxidea* shows that the large artery, accompanying the cardiac bronchus and supplying the Azygos lobe, corresponds topographically to the arterial branch which in *Taxidea* is seen to course ventro-mesad between *A* and *A'* and *B* to reach the bronchi derived from *B'*.

The cardiac bronchus appears as a secondary structure im-planted, at somewhat varying levels as we shall see, upon the stem-bronchus of the right side, its appearance being fore-shadowed by the arrangement of the arterial branch (*C*) of the bilateral hyparterial tree of *Taxidea.*

IV. Dicotyles torquatus—Collared Peccary.

Corrosion of bronchial system and pulmonary artery. Columbia University Museum, No. 1258. Pl. XIX.

This preparation exhibits a good type of the further modifications encountered among the Artiodactyla.

On the left side the entire bronchial distribution is hyparterial, the cephalic trunk *A* dividing into an apical (*A'*) and a lateral (*A''*) branch.

On the right side, as in *Canis*, the trunk *A* disappears by complete segmentation of its secondary branches, and the pulmonary artery crosses dorso-laterad, cephalad of the origin of *A''* from the stem-bronchus.

A' has shifted its point of origin, compared with *Canis*, further cephalad and appears as a lateral branch derived from the right side of the trachea.

The distribution of the caudal trunk in symmetrical. The stem-bronchus appears as an especially distinct structure, gradually diminishing in calibre in descent. *B'* appears as its first lateral branch caudad of the origin of *A* on the left and *A''* on the right side.

The cardiac bronchus and corresponding artery occupy the same position as in *Canis.*

V. Myrmecophaga jubata—Great Ant-Eater.

Corrosion preparation of bronchial system and pulmonary artery. Columbia University Museum, No. 479. Pl. XX.

A further advance in the migration cephalad of the right cephalic trunk *A* is noted in this preparation.

The entire right trunk, carrying its secondary branches *A'* and *A''*, has shifted cephalad on the stem-bronchus, becoming " eparterial," while on the left side the trunk maintains its original position below the artery.

The secondary branch *B'* on the left side appears reduced.

The cardiac bronchus is large, arising below the origin of *B'* from the medial margin of the stem-bronchus. The corresponding artery reaches the ventral surface of the cardiac bronchus by crossing obliquely meso-caudad over the stem-bronchus below the origin *B'*.

VI. Auchenia glama-pacos—Llama-Alpaca.

Corrosion of bronchial system and pulmonary artery. Columbia University Museum, No. 585. Pl. XXI.

The arrangement of the bronchial system on the right side follows in the main the artiodactyl type as represented by *Dicotyles*, with certain minor exceptions to be presently mentioned. The same number and disposition of the main branches is to be noted.

On the left side further extension cephalad of the apical portion of the lung has led to a division of the cephalic trunk *A*, repeating the one found on the right side.

The lateral branch *A''* occupies the position corresponding to the same branch on the right side, below the pulmonary artery. The apical branch *A'* has migrated cephalad, appearing as an "eparterial" bronchus arising close to the tracheal bifurcation from the left primary bronchus.

The arterial distribution is symmetrical ; the vessels accompanying the branch *A'* are on both sides derived from the beginning of the pulmonary artery, coursing on the ventral aspect of the corresponding bronchus.

This form, noted already by Aeby, constitutes the type which he describes as " bilateral eparterial bronchus, tracheal on right, bronchial on left side."

The cardiac bronchus is also shifted cephalad, arising from the ventro-mesal aspect of the stem-bronchus, opposite the origin of *A''* from the ventro-lateral surface.

The corresponding artery occupies a peculiar position. Instead of winding around the angle between stem-bronchus and *A''* caudad of the latter (see preceding types), the artery is derived from the caudal surface of the main pulmonary artery opposite the point where from the cephalic margin the apical vessel accompanying *A'* takes its origin. The artery descends on the ventral aspect of its bronchus. A similar bronchus is found on the left side, but the corresponding arterial branches are short trunks passing to their distribution from the main pulmonary artery dorsad of the stem-bronchus.

VII. Cebus capucinus—Capuchin Monkey.

Corrosion of bronchial system and pulmonary artery. Columbia University Museum, No. 488. Pl. XXII, Ventral view. Pl. XXIII, Dorsal view.

This type presents a somewhat peculiar arrangement of the cephalic trunks on both sides.

On the right side the separation of the two branches *A'* and *A''* is complete, the pulmonary artery occupying the interval between them. *A'* has migrated cephalad on the stem-bronchus, becoming "eparterial," and corresponding to the usual mammalian type of the right side.

On the left side the migration of the cephalic trunk *A* is complete compared with the preceding form (*Auchenia*). It is placed cephalad and dorsad of the point of accession of the main pulmonary artery to the stem-bronchus, and divides into the two secondary branches *A'* and *A''*.

We have, therefore, to follow Aeby's nomenclature for the moment, a "bilateral eparterial system." The eparterial bronchus of the right side, as usual, being furnished by the divorced and migrated apical branch *A'*, whereas, on the left side the entire cephalic trunk *A*, with its secondary branches *A'* and *A''*, becomes "eparterial."

This arrangement is exceptional, as the "bilateral eparterial type" is usually symmetrical. It leads, however, directly up to the condition presented by the two following forms, *Cebus niger* and *Phoca.*

The cardiac bronchus is well developed, derived from the right stem-bronchus between *A''* and *B'*.

The artery passes to the cardiac bronchus from the ventral aspect of the main pulmonary artery, before the same has crossed to the lateral aspect of the stem-bronchus, resembling the arterial arrangement noted in *Auchenia*, although a secondary branch (*C''*) is seen, in the dorsal view, winding around the stem-bronchus in the usual situation of the main artery of the Azygos lobe (Pl. XXIII).

VIII. Cebus niger—Capuchin Monkey.

Corrosion preparation of the bronchial system and pulmonary artery. Columbia University Museum, No. 484. Pl. XXIV, Dorsal view. Pl. XXV, Ventral view.

This type appears as the direct result of further development cephalad of the preceding form.

The cephalic trunks, *A*, of both sides appear as "eparterial bronchi," each dividing into the characteristic secondary branches *A'* and *A''*. On the right side the trunk *A* has shifted a little further cephalad, nearer to the tracheal bifurcation, than on the left side.

The main caudal branches and the cardiac bronchus are arranged as in the preceding form.

IX. Phoca vitulina—Harbor Seal.

Corrosion of bronchial system and pulmonary artery. Columbia University Museum, No. 584. Pl. XXVI, Ventral view.

This final type presents the complete "bilateral eparterial system," perfectly symmetrical; each cephalic trunk (*A*) is situated on the stem-bronchus close to the tracheal bifurcation, cephalad of the main pulmonary artery, and divides symmetrically into the secondary branches *A′* and *A″*. The corresponding arteries are situated ventrad, derived from the pulmonary artery close to its division into right and left main trunks.

In conformity with the complete bilateral symmetry of the tree a cardiac bronchus is not present.

SUMMARY.

If we briefly sum up the main facts just deduced from the examination of these specimens we find that a complete consecutive series can be established, leading from the symmetrical "bilateral hyparterial type" without cardiac bronchus (*Hystrix*), through gradual modifications, to the complete symmetrical "bilateral eparterial type" without cardiac bronchus (*Phoca*).

This series, to obtain a comprehensive view of the main features, may be schematically represented in Pl. XXVII.

Based on this comparison we may incorporate our conclusions in the following propositions :

1. The right and left lung agree, morphologically, in the type of their bronchial distribution.

2. The asymmetry—when observed—is apparent, not real, depending usually upon complete separation of the right cephalic trunk *A* into its two components *A′* and *A″*, and migration of *A′* cephalad, changing its original relation to bronchial stem and pulmonary artery ; more rarely the asymmetry depends upon the complete migration cephalad of the entire trunk *A*, carrying the secondary branches *A′* and *A″* (*Myrmecophaga*).

3. Aeby's hypothesis of the morphological equivalence of the middle right and upper left lobe of the human lung is, therefore, incorrect.

The proposition should read :

Right side.		Left side.
Upper + middle lobe	=	upper lobe.
Lower + cardiac lobe	=	lower lobe.

4. The active principle in changing and modifying the architecture of the lung is *not* the pulmonary artery (Aeby), but *mi-*

gration of the cephalic trunk *A*, or of its secondary branch *A'*, usually only on the right side, producing apparent asymmetry. This migration affords an opportunity for more complete development of the resulting terminal bronchial system, and for consequent increase in respiratory area.

5. In the majority of mammals this greater development of respiratory surface is confined to the right side, resulting in the formation of the so-called "eparterial bronchus," and also indicated by the development of a special accessory cardiac bronchus of the right side.

This physiological preponderance of right over left lung is especially well shown by the arrangement of the right lung in artiodactyls (*e.g.*, antelope), where the migration of the cephalic right bronchus has carried the same cephalad, beyond the bifurcation, to the trachea, and where the resulting voluminous upper lobe of the right lung at times extends completely across the mid-line to cap the apex of the more rudimentary left lung.

6. Except, therefore, for purposes of topography we should abandon the distinction of eparterial and hyparterial bronchi, at least to the extent of clearly recognizing the fact that in asymmetrical lungs every right "eparterial" bronchus finds its morphological equivalent among the "hyparterial" bronchi of the left side.

7. The impropriety of ascribing any morphological significance to the number of pulmonary lobes is apparent. The division into lobes is an entirely secondary character, not dependent upon the type of the bronchial distribution, but probably connected with unequal mobility in different segments of the thoracic walls. Lobe-formation is also subject to a considerable range of variation.

8. For the reasons above detailed the primitive type of the mammalian lung is the symmetrical "bilateral hyparterial form," the symmetrical "bilateral eparterial form" representing the *end-stage* in the process of evolution, not the *beginning* (Aeby, Wiedersheim).

9. The primitive type of division is practically dichotomous (*Hystrix, Taxidea*).

We can recognize two main trunks on each side, one cephalic, the other caudal. The cephalic trunk supplies the anterior and middle portion of the lung, the main migratory modifications in the different types taking place within its region of distribution.

The caudal trunk supplies the posterior and larger portion of the lung.

In the subsequent development of the stem-bronchus and its monopodic type of branching, characteristic of the majority of mammalian lungs, the following factors are active :

a. Complete segmentation of the tracheal bulla, producing the usual bifurcation. This establishes the proximal portion of the "stem-bronchus," and gives to the cephalic primary trunk *A* the position of a lateral branch derived from the same.

b. The caudal continuation of the stem-bronchus is composed of the primary caudal trunk *B* and its medial secondary branch B'', the lateral branch B' and subsequently developing lateral accessory branches appearing as the "ventral branches of the stem-bronchus" (Aeby).

c. The cardiac bronchus usually appears as a special accessory branch derived from the stem-bronchus of the right side only (exception *vide supra*, *Auchenia*).

10. In the majority of forms examined the pulmonary artery is not dorsal to the stem-bronchus, except in the terminal part. The position, as Narath has pointed out, is lateral or dorsolateral.

11. Hence, the distinction into "dorsal" and "ventral" branches, separated by the pulmonary artery, should be abandoned.

12. It will be seen that our results agree with the conclusions reached by Narath in regard to the equivalence of the anterior or cephalic branches of right and left side in a symmetrical lungs. We differ from him in our interpretation of the derivation of the "apical bronchus" which he regards as the dorsal branch of the first ventral bronchus.

We differ also as regards the above outlined phylogenetic development of the "stem-bronchus" and its monopodic system of branching.

If we seek for an explanation of the *cause* which leads to the migratory changes of the cephalic bronchus, I admit that we enter the realm of pure hypothesis. At the same time, the very general development throughout the mammalia of this type, with the resulting greater respiratory area of the right lung, may, I think, not improbably be referred to the development of the mammalian form of the systemic and pulmonary arteries. The fact which seems to me to be most significant in this respect is the development of the fourth and fifth embryonic arterial arches (Pl. XXVIII).

We know that with the septal division of the arterial trunk into systemic aorta and pulmonary artery the fifth arches on each side are assigned to the development of the latter vessel,[1] while the remaining arches are partially used in the elaboration of the adult arterial system.

If we consider the significance of the fœtal pulmonary inculation it will appear at once that the conditions differ on the right and left sides.

On the left side the greater quantity of the blood thrown from the right ventricle into the left pulmonary artery passes through the Botallian duct directly into the aorta, only a small portion traversing the left pulmonary circulation.

On the right side, however, with the early obliteration of the dorsal segment of the fifth arch, all the blood entering the right pulmonary artery is forced to traverse the entire pulmonary circulation, returning to the left auricle by the pulmonary veins.

I believe that we may properly ascribe to this fœtal circulatory condition a great share in the more marked development of the right as compared with the left lung.

This view is further supported by the conditions found in cases of "situs inversus," where the left lung develops the "eparterial" bronchus (Lit. 6, 8, 9).

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[1] It seems preferable, in general considerations, to disregard the existence of the sixth arch, demonstrated by Boas and Zimmerman, on account of the extremely temporary and evanescent character of the interpolated arch.

CONCLUSION.

I have brought this question to the attention of the Academy because I think it is high time to correct the erroneous views founded on Aeby's work. This is the more important, because his theories have been extensively transcribed and his diagrams reproduced in such of the anatomical text-books as deal with the matter at all. I subjoin a list of the anatomical handbooks most commonly in use with a brief statement of their expressions on the subject.

1. **Quain,** "Anatomy," Vol. III, Pt. IV, p. 176-179, follows Aeby's description, giving reproductions or reconstructions of three figures (195, 196, 197) and a somewhat extensive abstract of the text, stating that the right eparterial bronchus in man is not represented on the left side, and that accordingly the lobe which it supplies is also absent, making the upper left the homologue of the middle right lobe.

2. **Morris, Henry,** "Human Anatomy," Phila., 1893, p. 939–940, gives a very indifferent diagram of the ventral view of lungs, heart and pulmonary root, indicating on the right side bronchus, pulmonary artery, and pulmonary vein in the order named cephalocaudad; on the left side in the same order pulmonary artery, bronchus, pulmonary vein.

The text merely repeats this information in a brief statement.

3. **Gray, Henry,** "Anatomy, Descriptive and Surgical." New American Edition from the 13th English Edition, Philadelphia, 1897. P. 1109 gives a diagram (Fig. 706) of the human bronchial tree. after Aeby and a brief description founded on Aeby's work. P. 1117 gives in Fig. 710 a faulty view of the ventral aspect of the pulmonary roots, follows it (p. 1118) with the stereotyped description of the order of relations of the structures at the root of the lungs, and concludes (p. 1121) with a xylographic horror purporting to present the roots of the lungs from behind (Fig. 711).

4. **Wiedersheim, Robert,** "Lehrbuch der Vergleichenden Anatomie der Wirbelthiere," 2te Auflage, Jena, 1886, p. 262–266, gives in extenso Aeby's diagrams and conclusions, amplified by the investigations of M. Weber.

5. **Wiedersheim, Robert,** "Elements of the Comparative Anatomy of the Vertebrates" adapted from the 3d German edition, by W. N. Parker, London, 1897, p. 269.

Reproduces Aeby's diagram (Fig. 239), gives a brief resumé of Aeby's conclusions and asserts directly that the anterior lobes of the right and left lung are not homologous, but that the middle right lobe corresponds to the anterior left, and that a want of symmetry is thus created between right and left side, the right lung retaining one more element than the left. This statement is further emphasized by the lettering on fig. 240ª representing a ventral view of the human lungs.

6. **Joessel, G.,** "Lehrbuch, der topographisch-chirurgischen Anatomie," II, 1. Thorax. Bonn, 1890, p. 60. Gives Aeby's diagram and repeats his conclusions quite fully.

7. **Merkel, Fr.,** "Handbuch der Topographischen Anatomie," Bd. II, Lief. 2, p. 398 and 399, gives Aeby's main conclusions, but also refers to Narath's investigations and gives a schematic figure based on the latter's work. This is the only author who does not accept Aeby's views entirely.

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3. **Narath, Albert.** "Vergleichende Anatomie des Bronchialbaumes." *Verhandl. d. Anat. Gesellschaft.* VI. Versamml. 1892. Pp. 168–175.

4. **Hasse, C.** "Bemerküngen über die Athmung und den Bau der Lungen und über die Form des Brustkorbes bei den Menschen und Säugethieren." *Archiv. f. Anat. u. Entw.* Jahrg. 1893. Heft 5/6. Pp. 293–307.

5. **Hasse, C.** "Ueber den Bau der Menschlichen Lungen." *Ibid.,* Jahrg. 1892. Heft 5/6. Pp. 324–345.

6. **Aeby, Ch.** "Der Bronchialbaum des Menschen bei Situs inversus." *Arch. f. Anat. u. Phys.,* 1882.

7. **Zumstein, J.,** "Ueber den Bronchialbaum des Menschen und einiger Säugethiere." *Sitzber. d. Ges. z. Beförd. d. gesammten Naturwissenschaften zu Marburg,* 1889–92.

8. **Weber, Max,** "Ueber das Verhalten des Bronchialbaumes beim Menschen, bei Situs inversus." *Zoolog. Anzeiger*, 1881, No. 76.

9. **Leboucq, H.,** "Ein Fall von 'Situs inversus' beim Menschen, mit Rücksicht auf die Bronchialarchitectur," *Zool. Anz.*, 1881, No. 82.

10. **Ewart, William,** "The Bronchi and Pulmonary Blood-vessels, their Anatomy and Nomenclature; with a criticism of Professor Aeby's views on the Bronchial Tree of Mammalia and of Man." London, 1889.

PLATE XV.

PLATE XV.

Hystrix cristata—European Porcupine.

Corrosion of bronchial system and pulmonary artery. Ventral view. Columbia University Museum, No. 413.

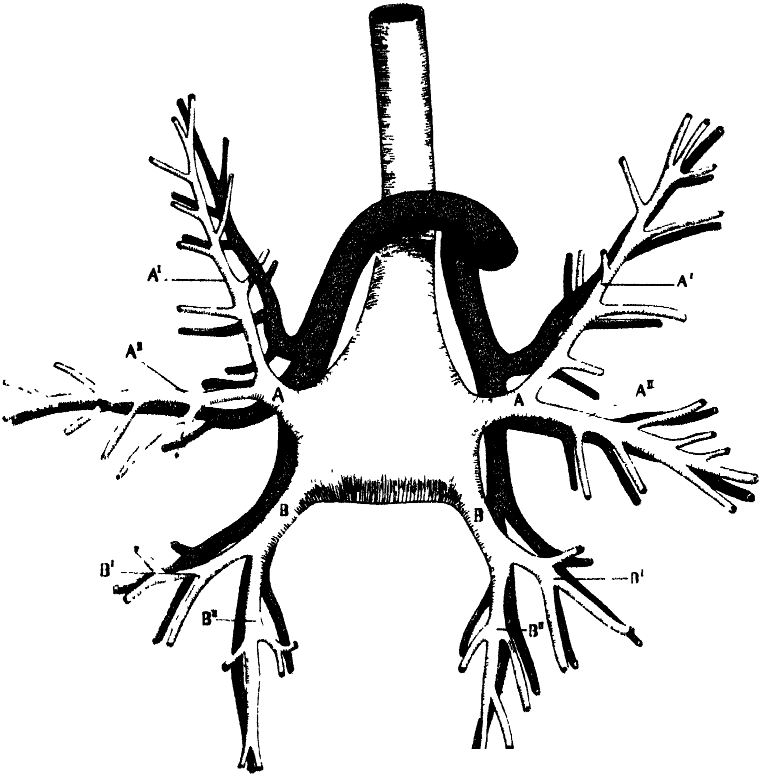
A'
A''
A
A
A'
A''
B
B
B'
B'
B''
B''

PLATE XVI.

PLATE XVI.

Taxidea americana—American Badger.

Young animal. Corrosion of bronchial system and pulmonary artery. Ventral view.

Columbia University Museum, No. 1254.

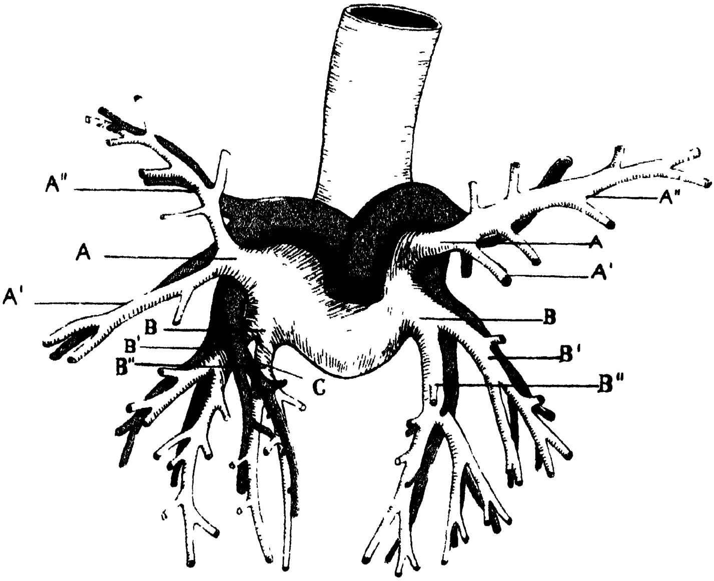
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PLATE XVII

PLATE XVII.

Taxidea americana—American Badger.

Adult ♂. Corrosion of bronchial system and pulmonary artery. Ventral view.

Columbia University Museum, No. 1255.

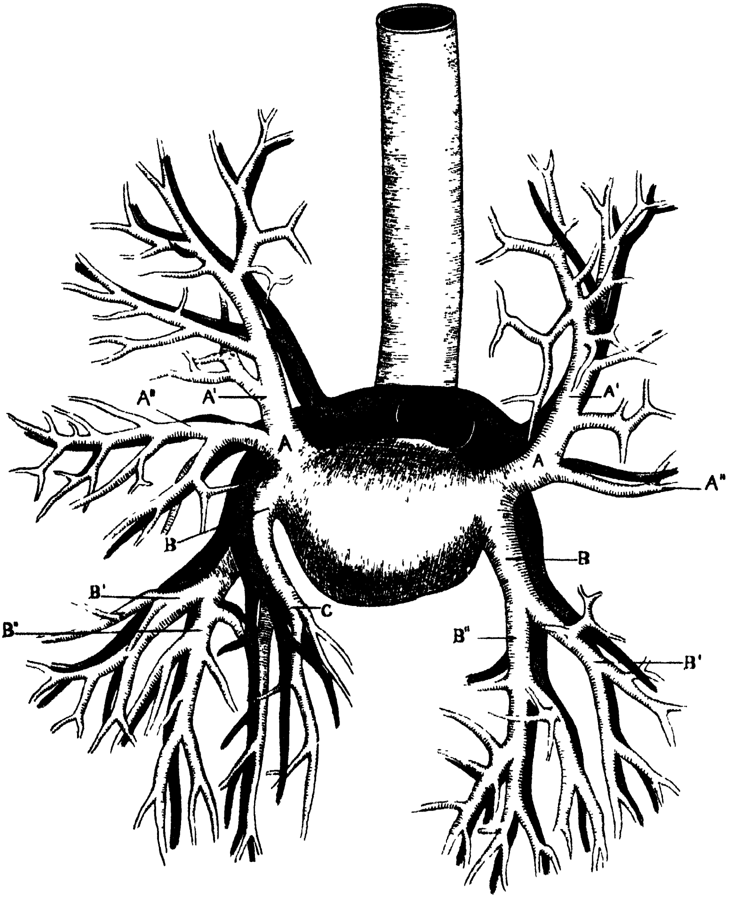
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PLATE XVIII.

PLATE XVIII.

Canis familiaris—Dog.

Corrosion of bronchial system and pulmonary artery. Ventral view.
Columbia University Museum, No. 1256.

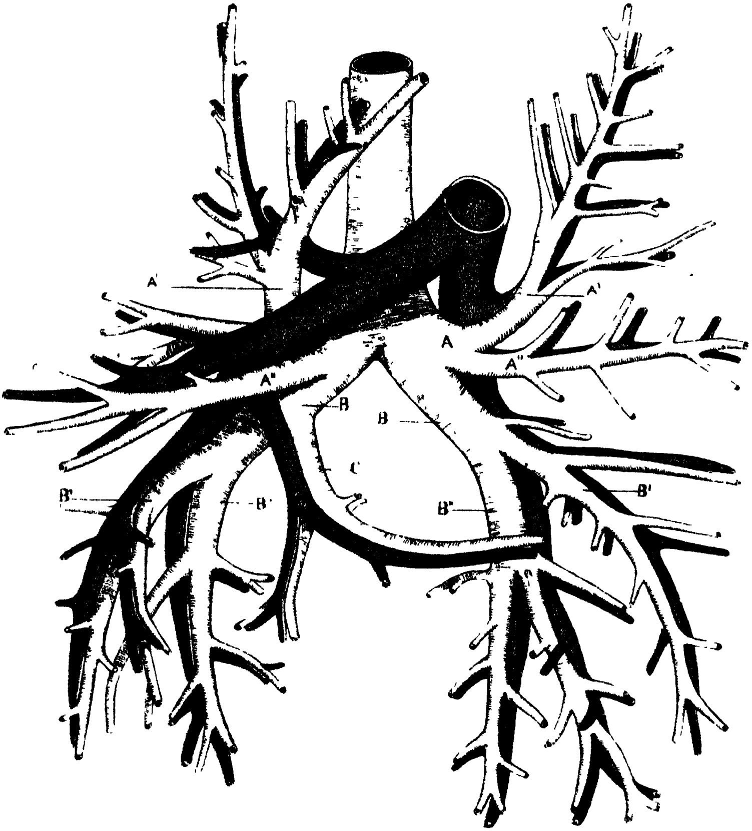
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PLATE XIX.

PLATE XIX.

Dicotyles torquatus—Collared Peccary.

Corrosion of bronchial system and pulmonary artery. Ventral view.
Columbia University Museum, No. 1258.

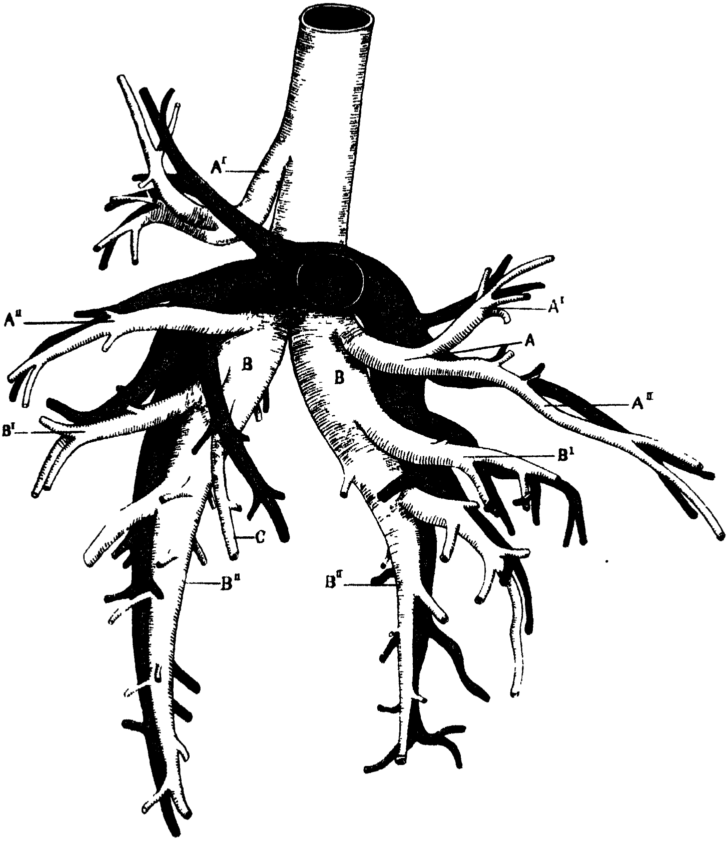
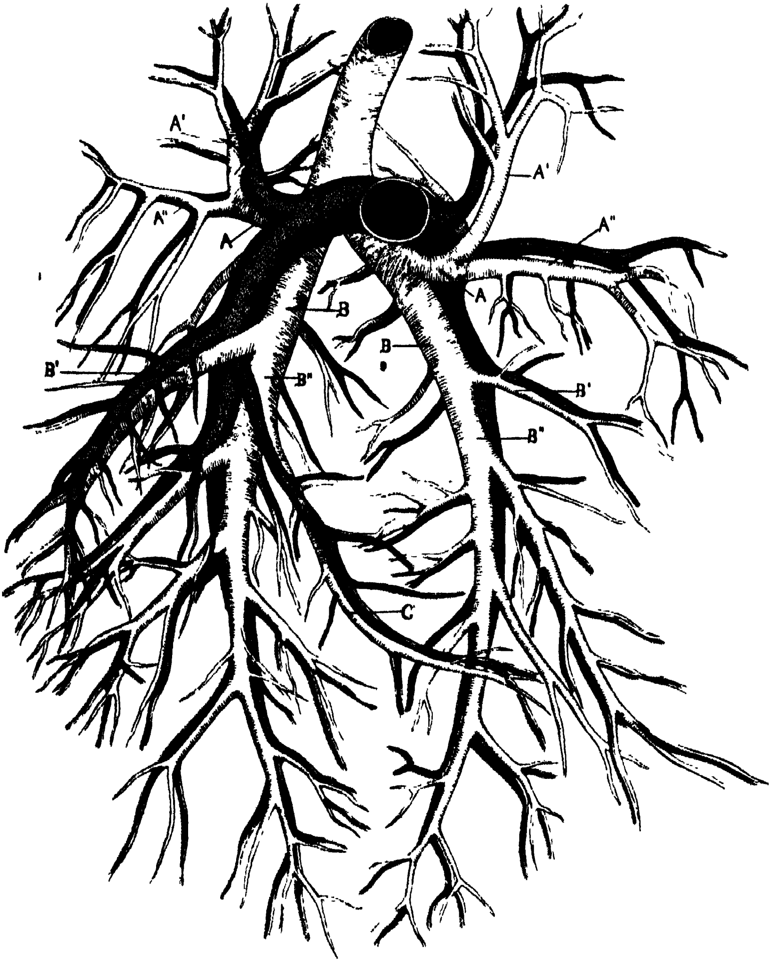

A^I
A^II
A^I
A
A^II
B
B
B^I
B^1
C
B^II
B^II

PLATE XX.

PLATE XX.

Myrmecophaga jubata—Great Ant-Eater.

Corrosion of bronchial system and pulmonary artery. Ventral view Columbia University Museum, No. 479.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B"
B"
C

PLATE XXI

PLATE XXI.

Auchenia glama-pacos—Llama-Alpaca.

Corrosion of bronchial system and pulmonary artery. Ventral view. Columbia University Museum, No. 585.

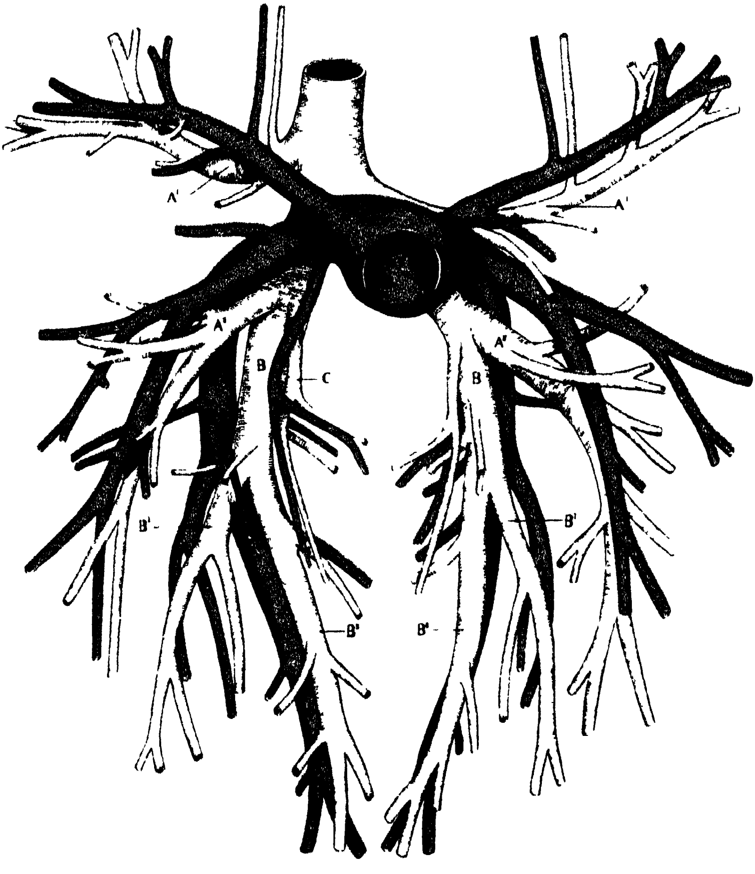
A'
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PLATE XXII.

PLATE XXII.

Cebus capucinus—Capuchin monkey.

Corrosion of bronchial system and pulmonary artery. Ventral view. Columbia University Museum, No. 488.

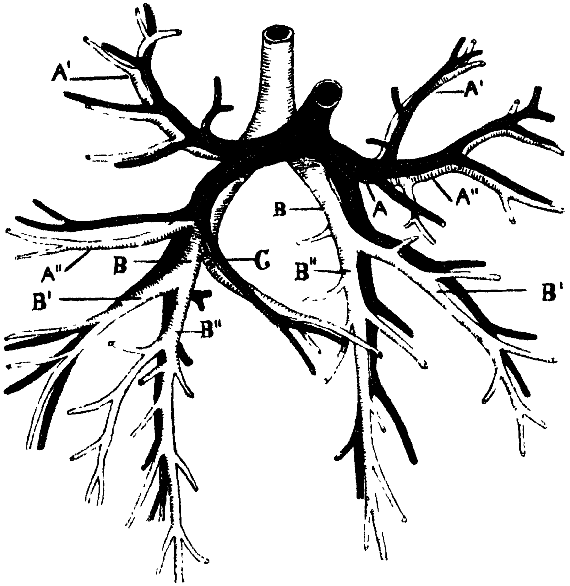
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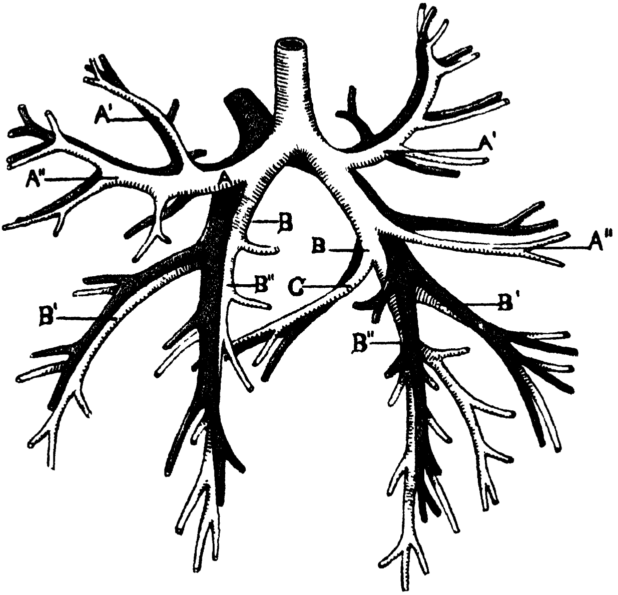
PLATE XXIII

PLATE XXIII.

Cebus capucinus—Capuchin monkey.

Corrosion of bronchial system and pulmonary artery. Dorsal view. Columbia University Museum, No. 488.


A'
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B
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C
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PLATE XXIV.

PLATE XXIV.

Cebus niger—Capuchin monkey.

Corrosion of bronchial system and pulmonary artery. Dorsal view. Columbia University Museum, No. 484.

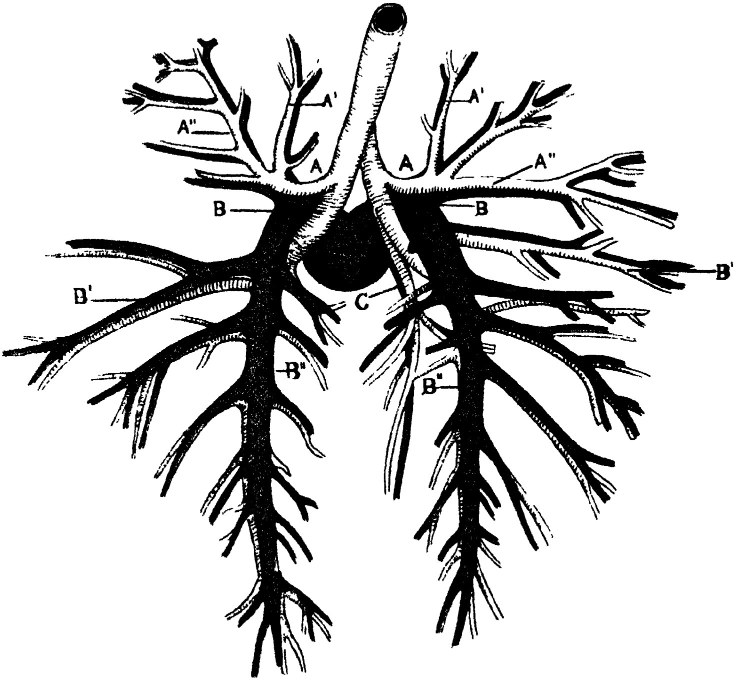
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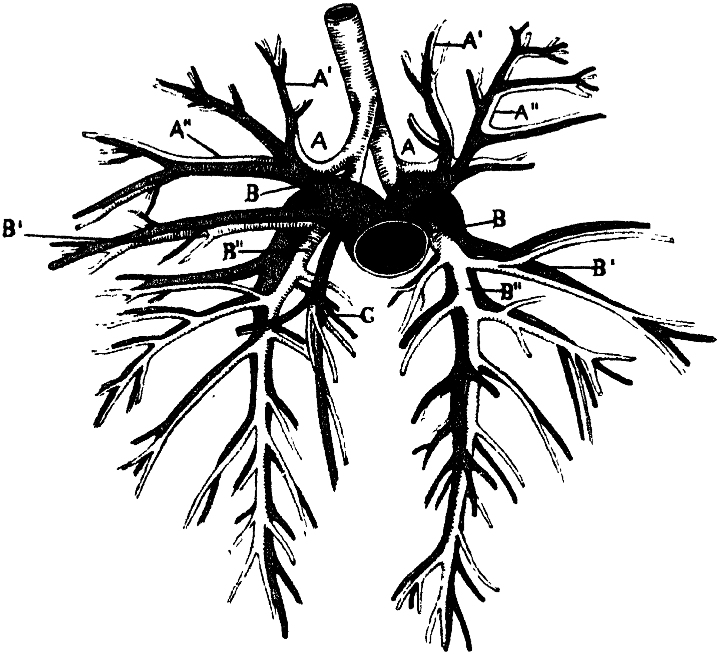
PLATE XXV.

PLATE XXV.

Cebus niger—Capuchin monkey.

Corrosion of bronchial system and pulmonary artery. Ventral view.
Columbia University Museum, No. 484.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B
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B'
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B'
B"
C

PLATE XXVI.

PLATE XXVI.

Phoca vitulina—Harbor Seal.

Corrosion of bronchial system and pulmonary artery. Ventral view.
Columbia University Museum, No. 584.

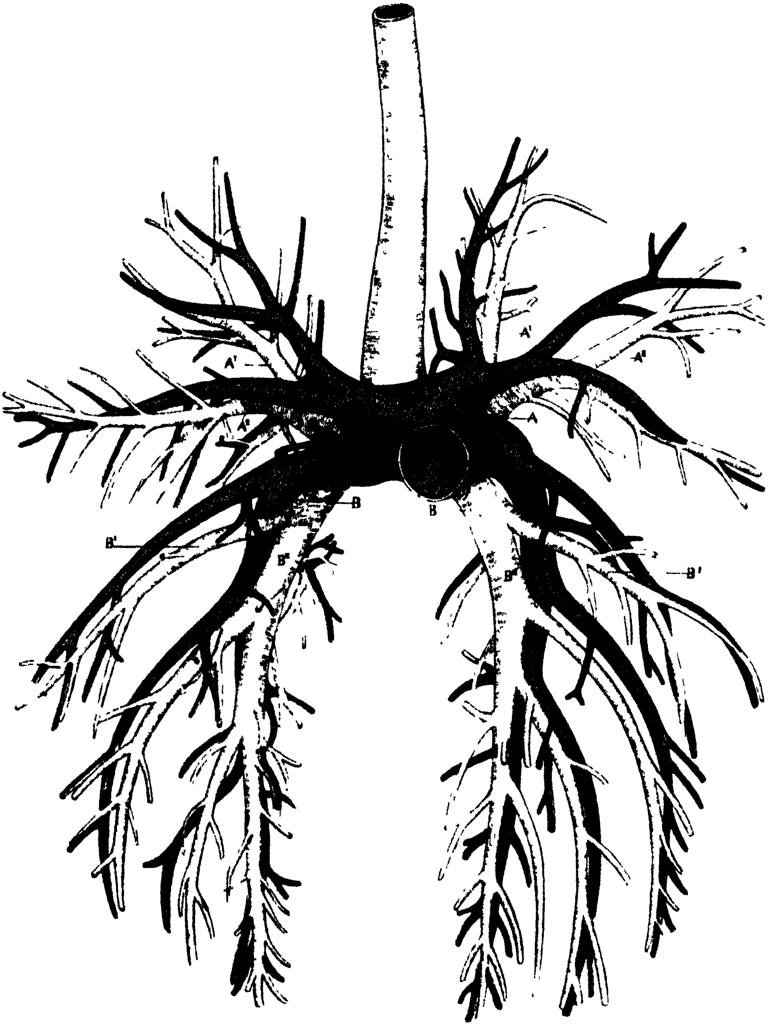
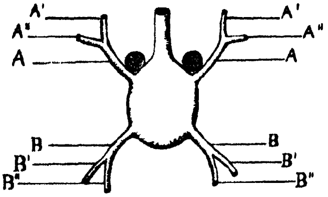

A¹
A¹
A²
A²
A
B
B
B¹
B¹
B²
B²

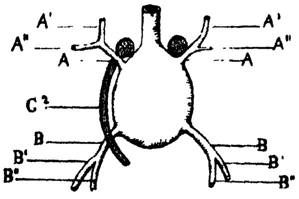
PLATE XXVII.

PLATE XXVII.

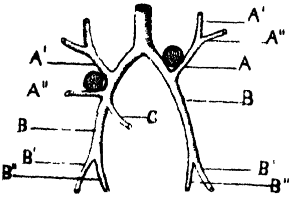
Schematic series, based on preparations described, showing types of mammalian bronchial tree and pulmonary artery.



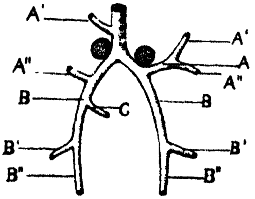
Hystrix cristata



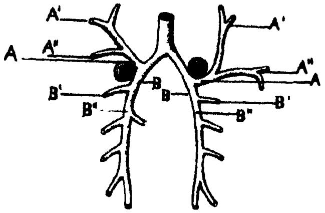
Taxidea Americana



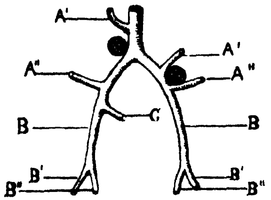
Canis familiaris



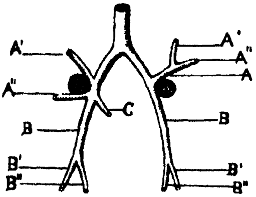
Dicotyles torquatus



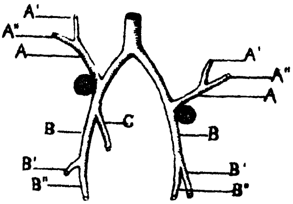
Myrmecophaga jubata.



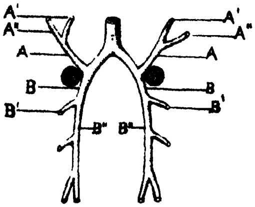
Auchenia glama-pacos.



Cebus capucinus



Cebus niger

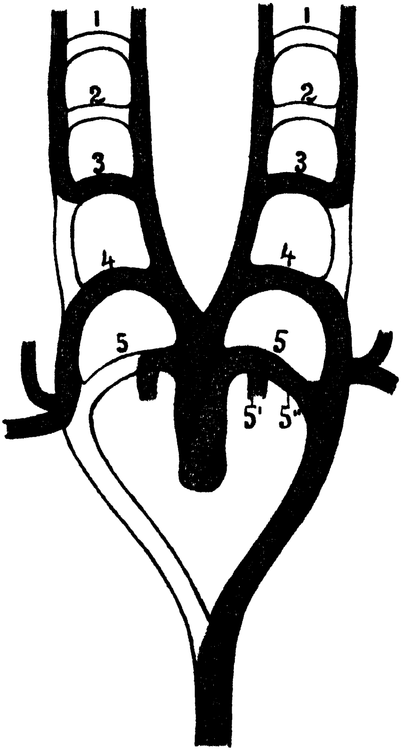


Phoca vitulina

PLATE XXVIII.

PLATE XXVIII.

Schema showing development of mammalian arterial system.


5''

[ANNALS N. Y. ACAD. SCI., XI, NO. 9, pp. 177 to 192, July 29, 1898.]

THE DEBT OF THE WORLD TO PURE SCIENCE.

ANNUAL ADDRESS OF THE RETIRING PRESIDENT.

J. J. STEVENSON.

(Read February 28, 1898.)

THE fundamental importance of abstruse research receives too little consideration in our time. The practical side of life is all-absorbent; the results of research are utilized promptly and full recognition is awarded to the one who utilizes, while the investigator is ignored. The student himself is liable to be regarded as a relic of medieval times, and his unconcern respecting ordinary matters is serviceable to the dramatist and newspaper witlet in their times of need.

Yet every thoughtful man, far away as his calling may be from scientific investigation, hesitates to accept such judgment as accurate. Not a few, engrossed in the strife of the market-place, are convinced that even from the selfish standpoint of mere enjoyment less gain is found in amassing fortunes or in acquiring power over one's fellows than in the effort to solve Nature's problems. Men scoff at philosophical dreamers, but the scoffing is not according to knowledge. The exigencies of subjective philosophy brought about the objective philosophy. Error has led to the right. Alchemy prepared the way for Chemistry, Astrology for Astronomy, Cosmogony for Geology. The birth of inductive science was due to the necessities of deductive science, and the greatest development of the former has come from the trial of hypotheses belonging in the border land between science and philosophy.

My effort this evening is to show that discoveries which have proved all-important in secondary results did not burst forth full-grown; that in each case they were, so to say, the crown of a structure reared painfully and noiselessly by men indifferent to this world's affairs, caring little for fame, and even less for wealth. Facts were gathered, principles were discovered, each falling into its own place until at last the brilliant crown shone out and the world thought it saw a miracle.

This done, I shall endeavor to draw a moral which it is hoped will be found worthy of consideration.

The heavenly bodies were objects of adoration from the earliest antiquity; they were guides to caravans on the desert as well as to mariners far from land; they marked the beginning of seasons or, as in Egypt, the limits of vast periods embracing many hundreds of years. Maps were made thousands of years ago showing their positions, the path of the sun was determined rudely, the influence of the sun and moon upon the earth was recognized in some degree and their influence upon man was inferred. Beyond these matters man with unaided vision and with knowledge only of elementary mathematics could not go.

Mathematical investigations by Arabian students prepared the means by which, after Europe's revival of learning, one without wealth gave a new life to astronomy. Copernicus, early trained in mathematics, during the last thirty years of his life spent the hours stolen from his work us a clerk and charity physician in mathematical and astronomical studies, which led him to reject the complex Ptolemaic system and to accept in modified form that bearing the name of Pythagoras. Tycho Brahe followed. A mere star-gazer at first, he became an earnest student, improved the instruments employed, and finally secured recognition from his sovereign. For twenty-five years he sought facts, disregarding none, but seldom recognizing economic importance in any. His associate, Kepler, profiting by his training under Brahe, carried the work far beyond that of his predecessors—and this in spite of disease, domestic sorrows and only too frequent experience of abject poverty. He divested the Copernicus hypothethis of many crudities and discovered the laws which have been utilized by astronomers in all phases of their work. He ascertained the causes of the tides; with the aid of the newly invented telescope made studies of eclipses and occultations, and just missed discovering the law of gravitation. He laid the foundation for practical application of astronomy to every-day life.

In the eighteenth century astronomy was recognized by governments as no longer of merely curious interest and its students received abundant aid. The improvement of the telescope, the discovery of the law of gravitation and the invention of logarithms had made possible the notable advance marking the close of the seventeenth century. The increasing requirements of accuracy led to exactness in the manufacture of instruments, to calculation and recalculation of tables, to long expeditions for testing methods as well as conclusions, until finally the suggestions of Copernicus, the physician, and of Kepler, the ill-fed invalid, became fact, and astronomical results were utilized to the advantage of mankind. The voyager on the ocean, the agriculturist on land, reap benefits from the accumulated observations of three centuries, though they know nothing of the principles or of the laborers by whom the principles were discovered. The regulation of chronometers as well as the fixing of boundary lines between great nations are determined by methods due to slow accumulation of facts, slower development in analysis and calculation, and even slower improvement in instruments.

Galvani's observation that frogs' legs twitch when near a friction machine in operation led him to test the effect of atmospheric electricity upon them. The instant action brought about the discovery that it was due, not to atmospheric influence, but to a current produced by contact of a copper hook with an iron rail. Volta pursued the investigation and constructed the pile which bears his name. With this, modified, Davy, in 1807, decomposed potash and soda, thereby isolating potassium and sodium. This experiment, repeated successfully by other chemists, was the precursor of many independent investigations which directed to many lines of research, each increasing in interest as it was followed.

Volta's crown of cups expanded into the clumsy trough batteries which were finally displaced in 1836 by Daniel's constant battery, using two fluids, one of which was cupric sulphate. De la Rue observed that as the sulphate was reduced, the copper was deposited on the surface of the outer vessel and copied accurately all markings on that surface. Within two or three years Jacobi and Spencer made the practical application of this observation by reproducing engravings and medals. Thus was born the science of electro-metallurgy. At first mere curiosities were made, then electro-plating in a wider way, the electrotype, the utilization of copper to protect more easily destructible metals, the preparation of articles for ornament and utility by covering baser metals with copper or silver or gold; while now the development of electro-generators has led to wide applications in the reduction of metals and to the saving of materials which otherwise would go to waste.

Oersted in 1819–20, puzzling over the possible relations of voltaic electricity to magnetism, noticed that a conductor carrying an electrical current becomes itself a magnet and deflects the needle. Sturgeon, working along these lines, found that soft iron enclosed in a coil, through which a current passes becomes magnetic, but loses the power when the current ceases. This opened the way for our own Henry's all-important discovery of the reciprocating electro-magnets and the vibrating armature—the essential parts of the magnetic telegraph. Henry actually constructed a telegraph in 1832, winding the wires around his class-room in Albany and using a bell to record the making and breaking signals. Here, as he fully recognized, was everything but a simple device for receiving signals.

Several years later, Professor Morse, dreaming night and day of the telegraph, was experimenting with Moll's electro-magnet and finding only discouragement. His colleague, Professor Gale, advised him to discard the even then antiquated apparatus and to utilize the results given in Henry's discussion. At once the condition was changed and soon the ingenious recording instrument bearing Morse's name was constructed. Henry's scientific discoveries were transmuted by the inventor's ingenuity into substantial glory for Morse, and proved a source of inconceivable advantage to the whole civilized world. Steinhal's discovery that the earth can be utilized for the return current completed the series of fundamental discoveries, and since that time everything has been elaboration.

Oersted's discovery respecting the influence of an electric current closely followed by that of Arago in the same direction opened the way for Faraday's complete discovery of induction, which underlies the construction of the dynamo. This ascertained, the province of the inventor was well defined, to conjure some mechanical appliance whereby the principle might be utilized. But here, as elsewhere, the work of discovery and that of invention went on almost *pari passu*; the results of each increased those of the other. The distance from the Clark and Page machines of the middle '30's, with their cumbrous horseshoe magnets and disproportionate expenditure of power, to the Siemens machine of the '50's was long, but it was no leap. In like manner, slow steps marked progress thence to the Gramme machine, in which one finds the outgrowth of many years of labor by many men, both investigators and inventors. In 1870, forty years after Faraday's announcement of the basal principle, the stage was reached whence progress could be rapid. Since that time the dynamo has been brought to such stage of efficiency that the electro-motor seems likely to displace not merely the steam engine, but also other agencies in direct application of force. The horse is passing away and the trolley road runs along the country highway; the longer railways are considering the wisdom of changing their power; cities are lighted brilliantly where formerly the gloom invited highwaymen to ply their trade; and even the kitchen is invaded by new methods of heating.

Long ago it was known that if the refining of pig iron be stopped just before the tendency to solidify became pronounced the wrought iron is more durable than that obtained in the completed process. This imperfectly refined metal was made frequently, though unintentionally and ignorantly. A short railroad in southwest Pennsylvania was laid in the middle 60's with iron rails of light weight. A rail's life in those days rarely exceeded five years; yet some of those light rails were in excellent condition almost fifteen years afterwards, though they had carried a heavy coke traffic for several years. But this process was uncertain, and the best puddlers could never tell when to stop the process in order to obtain the desired grade.

When a modification of this refining process was attempted on a grand scale almost contemporaneously by Martien, in this country, and Bessemer, in England, the same uncertainty of product was encountered—sometimes the process was checked too soon, at others pushed too far. Here the inventor came to a halt. He could use only what was known and endeavor to improve methods of application. Under such conditions the Bessemer process was apparently a hopeless failure. Another, however, utilized the hitherto ignored work of the closet investigator. The influence of manganese in counteracting the effects of certain injurious substances and its relation to carbon when present in pig iron were understood as matters of scientific interest. Mushet recognized the bearing of these facts and utilized them in changing the process. His method proved successful, but with thorough scientific forgetfulness of the main chance, he neglected to pay some petty fees at the Patent Office and so reaped neither profit nor popular glory for his work.

The Mushet process having proved the possibility of immediate and certain conversion, the genius of the inventor found full scope. The change in form and size of the converter, the removable base, the use of trunnions and other details, largely due to the American, Holley, so increased the output and reduced the cost that Bessemer steel soon displaced iron and the world passed from the age of iron into the age of steel.

Architectural methods have been revolutionized. Buildings, ten stories high, are commonplace; those of twenty no longer excite comment, and one of thirty arouses no more than a passing pleasantry respecting possibilities at the top. Such buildings were almost impossible a score of years ago, and the weight made the cost prohibitive. The increased use of steel in construction seems likely to preserve our forests from disappearance.

In other directions the gain through this process has been more important. The costly, short-lived iron rail has disappeared and the durable steel rail has taken its place. Under the moderate conditions of twenty-five years ago iron rails scarcely lasted more than five years; in addition the metal was soft, the limit of load was reached quickly, and freight rates, though high, were none too profitable.

But all changed with the advent of steel rails as made by the American process. Application of abstruse laws discovered by men unknown to popular fame enabled inventors to improve methods and to cheapen manufacture until the first cost of steel rails was less than that of iron. The durability of the new rails and their resistance to load justified increased expenditure in other directions to secure permanently good condition of the road bed. Just here, our fellow member, Mr. P. H. Dudley, made his contribution, whose importance can hardly be overestimated. With his ingenious recording apparatus it is easy to discover defects in the roadway and to ascertain their nature, thus making it possible to devise means for their correction and for preventing their recurrence. The information obtained by use of this apparatus has led him to change the shape and weight of rails, to modify the type of joints and the methods of ballasting, so that now a roadbed should remain in good condition and even improve during years of hard use.

But the advantages have not inured wholly to the railroad companies. It is true that the cost of maintenance has been reduced greatly; that locomotives have been made heavier and more powerful; that freight cars carry three to four times as much as they did twenty-five years ago, so that the whole cost of operation is very much less than formerly. But where the carrier has gained one dollar the consumer and shipper have gained hundreds of dollars. Grain and flour can be brought from Chicago to the seaboard as cheaply by rail as by water; the farmer in Dakota raises wheat for shipment to Europe; coal mined in West Virginia can be sold on the docks of New York at a profit for less than half the freight rate of twenty-five years ago. Our internal commercial relations have been changed and the revolution is still incomplete. The influence of the Holley-Mushet-Bessemer process upon civilization is hardly inferior to that of the electric telegraph.

Sixty years ago an obscure German chemist obtained an oily liquid from coal-tar oil, which gave a beautiful tint with calcium chloride; five years later another separated a similar liquid from a derivative of coal-tar oil. Still later, Hofmann, then a student in Liebig's laboratory, investigated these substances and proved their identity with an oil obtained long before by Zinin, from indigo, and applied to them all Zinin's term, Anilin. The substance was curiously interesting and Hofmann worked out its reactions, discovering that with many materials it gives brilliant colors. The practical application of these discoveries was not long delayed, for Perkins made it in 1856. The marvelous dyes, beginning with Magenta and Solferino, have become familiar to all. The anilin colors, especially the reds, greens and blues, are among the most beautiful known. They have given rise to new industries and have expanded old ones. Their usefulness has led to deeper studies of coal-tar products, to which is due the discovery of such substances as antipyrin, phenacetin, ichthyol and saccharin, which have proved so important in medicine.

One is tempted to dwell for a little upon Meteorology, that border land where physics, chemistry and geology meet, and to speak of the Signal Service system, the outgrowth of studies by an obscure school teacher in Philadelphia, but the danger of trespassing too far upon your endurance makes proper only this passing reference.

While men of wealth and leisure wasted their energies in literary and philosophical discussions respecting the nature and origin of things, William Smith, earning a living as a land surveyor, plodded over England, anxious only to learn, in no haste to explain. His work was done honestly and slowly; when finished as far as was possible with his means, it had been done so well that its publication checked theorizing and brought men back to study. His geological map of England was the basis upon which the British Survey began preparation of the detailed sheets, showing Britain's mineral resources.

In our country Vanuxem and Morton early studied the New Jersey Cretaceous and Eocene, containing vast beds of marl.

Scientific interest was aroused, and eventually a geological survey of the State was ordered by the Legislature. The appropriation was insignificant, and many of the legislators voted for it, hoping that some economic discovery might be made to justify their course in squandering the people's money. Yet there were lingering doubts in their minds and some found more than lingering doubts in the minds of their constituents. But when the marls were proved to contain materials which the chemist, Liebig, had shown to be all-important for plants, the conditions were changed and criticism ceased. The dismal sands of eastern New Jersey, affording only a scanty living for pines and grasses, were converted by application of the marl into gardens of unsurpassed fertility. Vanuxem's study of the stratigraphy and Morton's study of the fossils had made clear the distribution of marls and the survey scattered the information broadcast.

Morton and Conrad, with others scarcely less devoted, labored in season and out of season to systematize the study of fossil animals. There were not wanting educated men who wondered why students of such undoubted ability wasted themselves in trifling employment instead of doing something worthy of themselves so as to acquire money and fame. Much nearer to our own time, there were wise legislators who questioned the wisdom of " wasting money on pictures of clams and salamanders," though the same men appreciated the geologist who could tell them the depth of a coal bed below the surface. But the lead diggers of Illinois and Iowa long ago learned the use of palæontology, for the "lead fossil" was their guide in prospecting. The importance and practical application of this science, so largely the outgrowth of unappreciated toil in this country as well as in Europe, is told best in Professor Hall's reply to a patronizing politician's query, "And what are your old fossils good for?" "For this. Take me blindfolded in a balloon; drop me where you will; if I can find some fossils, I'll tell you in ten minutes for what mineral you may look and for what mineral you need not look."

Many regard Botany as a pleasing study, well fitted for women and dilletanti, but hardly deserving attention by strong men.

Those who speak thus only exercise the prerogative of ignorance, which is to despise that which one is too old or too lazy to learn. The botanist's work is not complete when the carefully gathered specimen has been placed in the herbarium with its proper label. That is but the beginning, for he seeks the relation of plants in all phases. In seeking these he discovers facts which often prove to be of cardinal importance. The rust which destroys wheat in the last stage of ripening, the disgusting fungus which blasts Indian corn, the poisonous ergot in rye, the blight of the pear and other fruits fall as much within the botanist's study as do the flowers of the garden or the sequoias of the Sierra. Not a few of the plant diseases which have threatened famine or disaster have been studied by botanists, unknown to the world, whose explanations have led to palliation or cure.

The ichthyologist, studying the habit of fishes, discovered characteristics which promptly commended themselves to men of practical bent. The important industry of artificial fertilization and the transportation of fish eggs, which has enabled man to restock exhausted localities and to stock new ones, is but the outgrowth of closet studies which have shown how to utilize Nature's superabundant supply.

The entomologist has always been an interesting phenomenon to a large part of our population. Insects of beauty are attractive, those of large size are curious, while many of the minuter forms are efficient in gaining attention. But that men should devote their lives to the study of unattractive forms is to many a riddle. Yet entomology yields to no branch of science in the importance of its economic bearings. The study of the life habits of insects, their development, their food, their enemies, a study involving such minute details as to shut men off from many of the pleasures of life and to convert them into typical students, has come to be so fraught with relations to the public weal that the State Entomologist's mail has more anxious letters than that of any other officer.

Insects are no longer regarded as visitations from an angry Deity, to be borne in silence and with penitential awe. The intimate study of individual groups has taught in many cases how to antagonize them. The scale threatened to destroy orange culture in California; the Colorado beetle seemed likely to ruin one of our important food crops; minute aphides terrified raisers of fruit and cane in the Sandwich Islands. But the scale is no longer a frightful burden in Califarnia; the potato bug is now only an annoyance, and the introduction of lady birds swept aphides from the Sandwich Islands. The gypsy moth, believed for more than a hundred years to be a special judgment, is no longer thought of as more than a very expensive nuisance. The curculio, the locust, the weevil, the chinch bug and others have been subjected to detailed investigation. In almost all cases methods have been devised whereby the ravages have been diminished. Even the borers which endangered some of the most important timber species are now understood and the possibility of their extermination has been changed into probability.

Having begun with the "infinitely great," we may close this summary with a reference to the "infinitely small." The study of fermentation processes was attractive to chemists and naturalists, each claiming ownership of the agencies. Pasteur, with a patience almost incredible, revised the work of his predecessors and supplemented it with original investigations, proving that a very great part of changes in organic substances exposed to the atmosphere are due primarily to the influence of low animals or plants whose germs exist in the atmosphere.

One may doubt whether Pasteur had any conception of the possibilities hidden in his determination of the matters at issue. The canning of meats and vegetables is no longer attended with uncertainty, and scurvy is no longer the bane of explorers; pork, which has supplied material for the building of railroads, the digging of canals, the construction of ships, can be eaten without fear. Flavorless butter can be rendered delicious by introduction of the proper bacteria; sterilized milk saves the lives of many children; some of the most destructive plagues are understood and the antidotes are prepared by the culture of antagonistic germs; antiseptic treatment has robbed surgery of half its terrors and has rendered almost commonplace operations which less than two decades ago were regarded as justifiable only as a last resort. The practice of medicine has been advanced by outgrowths of Pasteur's work almost as much as it was by Liebig's chemical investigations more than half a century ago.

In this review, the familiar has been chosen for illustration in preference to the wonderful, that your attention might not be diverted from the main issue, that the foundation of industrial advance was laid by workers in pure science, for the most part ignorant of utility and caring little about it. There is here no disparagement of the inventor; without his perception of the practical and his powers of combination the world would have reaped little benefit from the student's researches. But the investigator takes the first step and makes the inventor possible. Thereafter the inventor's work aids the investigator in making new discoveries to be utilized in their turn.

Investigation, as such, rarely receives proper recognition. It is usually regarded as quite a secondary affair in which scientific men find their recreation. If a geologist spends his summer vacation in an effort to solve some perplexing structural problem he finds on his return congratulations because of his glorious outing; the astronomer, the physicist and the chemist are all objects of semi-envious regard because they are able to spend their leisure hours in congenial amusements; while the naturalist, enduring all kinds of privation, is not looked upon as a laborer because of the physical enjoyment which most good people think his work must bring.

It is true that investigation, properly so-called, is made secondary, but this because of necessity. Scientific men in government service are hampered constantly by the demand for immediately useful results. Detailed investigation is interrupted because matters apparently more important must be considered. The conditions are even more unfavorable in most of our colleges and none too favorable in our greater universities. The "literary leisure" supposed to belong to college professors does not fall to the lot of teachers of science, and very little of it can be discovered by college instructors in any department. The intense competition among our institutions requires that professors be magnetic teachers, thorough scholars, active in social work, and given to frequent publication, that being prominent they may be living advertisements of the institution. How much time, opportunity or energy remains for patient investigation some may be able to imagine.

The misconception respecting the relative importance of investigation is increased by the failure of even well-educated men to appreciate the changed conditions in science. The ordinary notion of scientific ability is expressed in the popular saying that a competent surgeon can saw a bone with a butcher knife and carve a muscle with a handsaw. Once, indeed, the physicist needed little aside from a spirit lamp, test tubes and some platinum wire or foil; low power microscopes, small reflecting telescopes, rude balances and home-made apparatus certainly did wonderful service in their day; there was a time when the finder of a mineral or fossil felt justified in regarding it as new and in describing it as such, when a psychologist needed only his own great self as a basis for broad conclusions respecting all mankind. All of that belonged to the infancy of science, when little was known and any observation was liable to be a discovery, when a Humboldt, an Arago or an Agassiz was possible. But all is changed; workers are multiplied in every land; study in every direction is specialized; men have ceased the mere gathering of facts and have turned to the determination of relations. Long years of preparation are needed to fit one to begin investigation; familiarity with several languages is demanded; great libraries are necessary for constant reference, and costly apparatus is essential even for preliminary examination. Where tens of dollars once supplied the equipment in any branch of science, hundreds, yes thousands, of dollars are required now.

Failure to appreciate the changed conditions induces neglect to render proper assistance. As matters now stand, even the wealthiest of our educational institutions cannot be expected to carry the whole burden, for endowments are insufficient to meet the too rapidly increasing demand for wider range of instruction. It is unjust to expect that men, weighted more and more by the duties of science teaching, involving too often much physical labor, from which teachers of other subjects are happily free, should conduct investigations at their own expense and in hours devoted by others to relaxation. Even were the pecuniary cost comparatively small, to impose that would be unjust, for, with few exceptions, the results are given to the world without compensation. Scientific men are accustomed to regard patents much as regular physicians regard advertising.

America owes much to closet students as well as to educated inventors who have been trained in scientific modes of thought. The extraordinary development of our material resources—our manufacturing, mining and transporting interests—shows that the strengthening of our educational institutions on the scientific side brings actual profit to the community. But most of this strengthening is due primarily to the unremunerated toil of men dependent on the meagre salary of college instructors or government officials in subordinate positions. Their aptitude to fit others for usefulness, coming only from long training, was acquired in hours stolen from sleep or from time needed for recuperation. But the labors of such men have been so fruitful in results that we can no longer depend on the surplus energy of scientific men, unless we consent to remain stationary. If the rising generation is to make the most of our country's opportunities it must be educated by men who are not compelled to acquire aptness at the cost of vitality. The proper relation of teaching labor to investigation labor should be recognized, and investigation, rather than social, religious or political activity, should be a part of the duty assigned to college instructors.

Our universities and scientific societies ought to have endowments specifically for aid in research. The fruits of investigations due to Smithson's bequest have multiplied his estate hundreds of times over to the world's advantage. He said well that his name would be remembered long after the names and memory of the Percy and Northumberland families had passed away. Hodgson's bequest to the Smithsonian is still too recent to have borne much fruit, but men already wonder at the fruitfulness of a field supposed to be well explored. Nobel knew how to supply the results of science; utilizing the chemist's results, he applied nitro-glycerine to industrial uses; similarly, he developed the petroleum industry of Russia, and, like that of our American petroleum manufacturers, his influence was felt in many other industries of his own land and of the Continent. At his death he bequeathed millions of dollars to the Swedish Academy of Science, that the income might be expended in encouraging pure research. Smithson, Hodgson and Nobel have marked out a path which should be crowded with Americans.

The endowment of research is demanded now as never before. The development of technical education, the intellectual training of men to fit them for positions formerly held by mere tyros, has changed the material conditions in America. The surveyor has disappeared; none but a civil engineer is trusted to lay out even town lots; the founder at an iron furnace is no longer merely a graduate of the casting-house—he must be a graduate in metallurgy; the manufacturer of paints cannot entrust his factory to any but a chemist of recognized standing; no graduate from the pick is placed in charge of mines—a mining engineer alone can gain confidence; and so everywhere. With the will to utilize the results of science there has come an intensity of competition in which victory belongs only to the best equipped. The profit awaiting successful inventors is greater than ever and the anxious readiness to supply scientific discoveries is shown by the daily records. The Roentgen rays were seized at once and efforts made to find profitable application; the properties of zirconia and other earths interested inventors as soon as they were announced; the possibility of telegraphing without wire incited inventors everywhere as soon as the principle was announced.

Nature's secrets are still unknown and the field of investigation is as broad as ever. We are only on the threshold of discovery, and the coming century will disclose wonders far beyond any yet disclosed. The atmosphere, studied by hundreds of chemists and physicists for a full century, proved for Rayleigh and Ramsay an unexplored field within this decade. We know nothing yet. We have gathered a few large pebbles from the shore, but the mass of sands is yet to be explored.

And now the moral has been drawn. The pointing is simple. If America, which, more than other nations, has profited by science, is to retain her place Americans must encourage, even urge, research, must strengthen her scientific societies and her universities, that under the new and more complicated conditions her scientific men and her inventors may place and keep her in the front rank of nations.

NEW YORK UNIVERSITY,
February, 1898.

[ANNALS N. Y. ACAD. SCI., XI, No. 10, pp. 193 to 217, July 29, 1898.]

DESCRIPTION OF SOME MARINE NEMERTEANS OF PUGET SOUND AND ALASKA.

B. B. GRIFFIN.

(Read March 14, 1898.)

BRADNEY BEVERLEY GRIFFIN died of pneumonia on March 26th—less than a fortnight after the present paper was read before the Academy. The editor of the ANNALS has now sent me the proof for revision and has arranged that a brief notice of his life and work should be inserted as its preface.

Mr. Griffin came rightfully by his deep interest in science, for his forefathers on both sides had been prominent in the learned professions, that of medicine especially. His father, Dr. Bradney Griffin, although dying young, was a well-known practitioner in New York. Mr. Griffin's mother is of the Hollister family: his paternal grandmother was a du Barrière, one of whom together with other nobles emigrated to this country during the French Revolution.

Mr. Griffin received his first degree in 1894, graduating with highest honors, at the College of the City of New York. He there evinced a remarkable bent for zoölogy. Continuing his studies in the graduate Department of Columbia University he would have taken the Degree of Doctor of Philosophy at the present Commencement. He had held the position of University Fellow in Zoölogy and had taken part for two years in the summer expeditions to the northwest coast.

His published writings appear, with one exception, in the Transactions of the Academy. Their results are of permanent value and have already received marked attention both in this country and abroad. His mind was mature and none of us knew before his death that he was but twenty-six. His work showed to all, as memorial notices in foreign journals testify, that he was an investigator of rare promise; but those who knew him well can alone understand how much he would have contributed to zoölogical knowledge had his life been spared. I have never known a more perfect example of sacrificing devotion to a life's work. He gave his best energy—more than his health could spare—to zoölogy for zoölogy's sake. Personally, he was retiring, asked for nothing and cared for nothing in the way of material advancement. His industry was incessant, and was rarely directed in vain; he was conscientious even to the least of things; he made it clear to us that his ideals were the highest and that he did as he believed.

BASHFORD DEAN.

COLUMBIA UNIVERSITY, July 12, 1898.

PUBLISHED WRITINGS BY MR. GRIFFIN.

'96. The History of the Achromatic Structures in the maturation and fertilization of Thalassema. *Trans. N. Y. Acad. Sci.*, Vol. XV, pp. 163–176, pls. IX–XI.

'97 (1) A brief account of the work of collecting in Puget Sound and on the Pacific coast. (With others.) *Ibid.*, Vol. XVI, pp. 33–43, pl. I.

(2) Notes on the distribution and habits of some Puget Sound Invertebrates. (With N. R. Harrington.) *Ibid.*, pp. 152–165.

(3) Adaptation of the shell of Placuanomia to that of Saxidomus, with remarks on shell adaptation in general. *Ibid.*, pp. 77–99.

'98 (1) Description of some marine Nemerteans of Puget Sound and Alaska. (The present paper.)

(2) The Maturation and Fertilization of Thalassema. A thesis for the degree of Doctor of Philosophy. *Journal of Morphology.* (Shortly to appear.)

I. INTRODUCTION.

The forms here described were collected by the writer while a member of the Columbia University expeditions of 1896 and 1897 to Puget Sound and Alaska. During the first of the summers spent on the Pacific coast about 10–15 different forms were collected, all from the region about Port Townsend, Washington. The work of the second summer added about 15 Alaskan forms to the collection, besides three additional species from Puget Sound.

Upon the return the writer lost by shipwreck not only the Alaskan material, but all the previously prepared sections and much valuable literature, together with manuscripts including notes upon the color, form, habits and habitats of the living animals. The consequent necessity of replacing the literature. and resectioning the entire set of forms has, as may be readily understood, greatly delayed the publication of the specific descriptions.

The collections were made with the view of accumulating material for a monograph of the Nemerteans of the Pacific coast of the United States, and it is hoped that the present brief notice will be followed by a more extensive work with colored plates. The special interest attaching to certain of the forms (*e. g.*, *Carinoma*), as well as the general importance of the formal peculiarities of heretofore unexplored regions, will, it is hoped, prove a sufficient excuse for the publication of the present paper.

The species here described do not represent the entire number collected, since, in addition to those lost by shipwreck, several have been omitted in which the material was either too poorly preserved or too scanty for adequate determination.

As regards terminology, Montgomery's term ('96) mesenchyme will be used to designate that tissue formerly known as "parenchyme," "body-parenchyme" and "gelatinous tissue." The four vascular trunks of the mesonemerteans will be distinguished as dorso-lateral and ventro-lateral vessels (=respectively "Rhynchocölomseitengefässe" and "Seitengefässe" of Bürger, "supra-proboscidian-sheath-vessels" and "blood vessel" of Oudemans).

The writer wishes to express his grateful acknowledgements to Professor H. P. Johnson, of the University of California, for his very kind assistance in obtaining southern specimens of *Emplectonema viride* Stimpson. He also feels indebted to Mr. Mutty, of Port Townsend, for his permission to use one of his buildings as a laboratory, and to Mr. Shaffer for his kind loan of collecting appliances.

II. HISTORICAL.

During the years 1857–58 there appeared in the *Proceedings* of the Philadelphia Academy a series of preliminary papers by Dr. William Stimpson, in which he briefly described the invertebrates collected upon the North Pacific Exploring Expedition (1853–56). The collections made by Dr. Stimpson include, among other groups, thirty-three species of Nemerteans, obtained at points along the coasts of North America and Asia, though principally from Japan and China.

Stimpson arranged his thirty-three species under seventeen genera, of which the following ten were new: *Diplopleura*, *Tæniosoma*, *Dichilus*, *Cephalonema*, *Emplectonema*, *Diplomma*, *Dicelis*, *Polina*, *Tatsnoskia* and *Cosmocephalia*.[1] One half of the new genera have now proved synonyms. Thus *Dichilus* and *Cosmocephalia* = *Amphiporus* (Verrill '92); *Tæniosoma* = *Eupolia* (Bürger '95 (2)); *Polina*, according to Bürger = *Eupolia*, but according to Verrill = *Amphiporus*. Those of the other half (viz. *Cephalonema*, *Diplomma*, *Dicelis* and *Tatsnoskia*) have not, to the knowledge of the present writer, been identified with any of the valid genera of the present day. Their fate must await further work upon these Japanese and Chinese forms. Of the remaining seven genera, four (*Lineus*, *Cerebratulus*, *Valencinia* and *Tetrastemma*) were well recognized at the time Stimpson wrote, and are still valid; while three (*Meckelia*, *Polystemma* and *Serpentaria*) are synonyms of *Cerebratulus*, *Amphiporus* and *Cerebratulus* respectively.

Two of the ten new generic terms invented by Stimpson represent valid genera, and, as Verrill ('95) has urged, should, by virtue of priority, supersede those now generally accepted by European writers. *Emplectonema* is sufficiently well defined, so that "Sicher ergiebt sich trotz der unvollkommenen Diagnosen dass 49 und 55 mit *Eupolia* und 52 (*Emplectonema*) mit *Eunemertes* zusammenfallen." (Bürger '952). As *Emplectonema* long antedates *Eunemertes* (Vailant '90), it should stand for this genus. Similarly *Diplopleura* is at once recognized as identical with *Langia* (Hubrecht '79) and has priority.

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[1] His classification throughout is superficial and based in the main upon trivial external characters.

Owing to loss of plates and material in the great Chicago fire, Stimpson was unable to publish his detailed descriptions and colored drawings. The *Prodromus*, accordingly, together with a brief paper on Chinese and Japanese forms (1855), represents, to the knowledge of the present writer, all the published work upon North Pacific Nemerteans up to date.

Of the species obtained by the present writer, one (*Emplectonema viride* Stimpson) was described in the *Prodromus*; the other (*Emplectonema violaceum* Bürger) was described by Bürger ('96) from the Chilian Coast, while the remainder do not seem to have been noticed by either. Among the latter is one form of special interest in that its genus, which represents a transitional type, has heretofore been represented by two species only, both of which are very rare. This form *which occurs abundantly* in the Puget Sound region, is a new species of *Carinoma*. In order, however, to make clear the relationships and significance of *Carinoma*, it will be necessary to briefly trace the historical development of Nemertean taxonomy.

One of the most servicable taxonomic systems was that proposed by Max Schultze in 1852, which divided the Nemerteans into the well-known ENOPLA and ANOPLA, based upon the re-respective presence or absence of calcareous stylets in the proboscis. Although this system was generally accepted and adopted in the older text-books, it finally became evident that the mere presence or absence of stylets is no *certain* indication of affinity. Thus forms are known whose inner organization in other respects conforms to the Enoplous type, yet lack the stylets (*e.g.*, *Malacobdella*, *Pelagonemertes*). Moreover, the Anopla proved a very heterogeneous assemblage, since under this term forms were included that differ as widely from each other as they do from the Enopla (*e.g.*, *Carinella*, *Cephalothrix*, *Cerebratulus*). These faults were partially removed by Hubrecht ('79) in the following system :

1. PALÆONEMERTINI.

No deep lateral fissure on the side of the head. No stylet in the proboscis. Mouth behind ganglia.

Carinella,
Polia,
Cephalothrix,
Valencinia.

2. SCHIZONEMERTINI.

A deep longitudinal lateral fissure on each side of the head, from the bottom of which a ciliated duct leads into the posterior lobe of the ganglion. Lateral nerves between the longitudinal and inner circular muscular coat of the body wall. Nervous tissue deeply tinged with hæmoglobin. Mouth behind the ganglia.

Lineus,
Cerebratulus,
Borlasia,
Langia.

3. HOPLONEMERTINI.

One or more stylets in the proboscis. Mouth generally situated before the ganglia. Lateral nerves inside the muscular coats of the body-wall. No deep longitudinal fissures on each side of the head.

Drepanophorus,
Tetrastemma,
Oerstedia,
Amphiporus,
Prosorhochmus,
Nemertes.

The above system, the result of a deeper study of the inner organization of these worms, marked an important advance in taxonomy. A single character (presence or absence of stylets) is here no longer taken as the basis of division, but a group of characters ; and, moreover, the importance of the number and position of the muscular coats of the body-wall in relation to the nerve cords commences for the first time to be recognized.

But excellent and serviceable as the Hubrechtian system was, it still possessed a defect which became more conspicuous with increase of our knowledge of the comparative anatomy and embryology. It still associated under the term PALÆONEMERTINI such forms as *Carinella*, *Cephalothrix* and *Polia* (= *Eupolia* Hubrecht '87), the last named type being more closely related to the SCHIZONEMERTINI than to *Carinella*. The following sentence from Oudemans ('85) shows how quickly this defect became obvious with careful comparative study. "Though the families of the *Valenciniidæ* and the *Poliidæ* belong to the PALÆONEMERTEA, they, with respect to their vascular and nephridial system, already approach the SCHIZONEMERTEA. To avoid confusion, I will here employ the expression, "Palæo-type," "Schizo-type" and "Hoplo-type." Bürger ('90) went even further, and, after a severe criticism of Hubrecht's system, proposed a return to the Anopla and Enopla of Max Schultze. During the next two years, however, Bürger ('91 and '92) elaborated and published a new system, which of all those heretofore proposed seems to come the nearest to expressing the true interrelationship of the main groups of Nemerteans.

Before taking up Bürger's system in detail we must glance briefly at the phylogenetic theories as influenced by the discovery of *Carinoma*. All are agreed that the epithelial position of the nerves in *Carinella* is a primitive feature. Accordingly the derivation of the remaining Nemertean orders from *Carinella*-like ancestors involves an inward migration of the nerve-cords. Even before the discovery of *Carinoma* a fairly complete series could be arranged from *Carinella* with its epithelial nervous system, through *Cephalothrix* with nerve-cords in the longitudinal layer, to *Cerebratulus* in which the nerve-cords have apparently migrated further inward to lie closely appressed (and sometimes indenting) the inner circular muscle layer, leading finally to the Enoplous types with the nerves internal to *all* the muscular coats. (Compare figures in Hubrecht '87.)

In 1875 McIntosh obtained at Southport, England, a species which he described as *Valencinia armandi* n. sp. The careful description of this form by its discoverer (MacIntosh '75) and the able anatomical investigations of Oudemans ('85) made it clear that *Valencinia armandi* is not only the representative of a distinct type (allied to *Cephalothrix*), but a form in many respects intermediate between *Carinella* and other Nemerteans. The special interest centers in the fact that anteriorly the nerve-cords lie in a similar position to those of *Carinella* (although surrounded by a thin layer of longitudinal muscles), while more posteriorly they break through the outer circular layer and lie for the rest of their course within the longitudinal layer. Oudemans was thus thoroughly justified in creating the new genus *Carinoma* for its reception. For twenty years the form remained the sole representative of its genus. In 1895 Bürger described the *C. patagonica* from some very scanty material collected at Punta Arenas, Patagonia. Of this material he observes: "Über ihr Aussehen im Leben fehlen leider Angaben." In *C. patagonica* the nerves lie wholly within the longitudinal muscle layer, so that within the limits of the genus *Carinoma* we have accomplished the theoretically required migration of the nerves through the circular muscle layer. It now became easy[1] to derive the Enopla directly from *Carinella* through *Carinoma* and *Cephalothrix*,[2] while the *Schizonemertean* type (including the Eupolidæ) comes off as an independent side branch from an ancestor of *Carinoma*, which retained the nerve-cords outside of the circular muscles, but lost the inner circular layer and developed a new longitudinal layer beneath the basal membrane of which *Carinoma armanda* shows rudiments.[3]

These points are all clearly recognized in Bürger's taxonomic system. *Carinella* with *Carinoma* and *Hubrechtia* constitute the first and most primitive order PROTONEMERTINI; *Carinoma* and *Cephalothrix* are ranked as an independent order MESONEMERTINI;

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[1] Cf. Bürger '95 (2).

[2] *Carinoma*, while more primitive as regards the nerve-cords and presence of nephridia, seems to have lost the cephalic organs still retained in *Cephalothrix* (compare Joubin '90).

[3] Such an ancestor Bürger believes to be realized in *Hubrechtia desiderata* (v. Kennel).

the Enopla constitute the METANEMERTINI, while the remaining representatives of Hubrecht's *Palæonemertini* (viz., the Eupolidæ) are grouped with the *Schizonemertini* under the ordinal term HETERONEMERTINI.

Thus with the establishment of Bürger's system there appears to vanish the last vestige of artificiality in the ordinal classification, and for the first time we have a system that may be called a natural one.

III. SPECIAL DESCRIPTIONS.

PROTONEMERTINI.

1. **Carinella sexlineata** n. sp.

In form, color and internal anatomy this species very closely resembles *C. superba* (Kölliker), being marked by creamy white lines and annulations disposed upon a ground color of reddish brown. The principal difference lies in the *pattern* of the markings, which renders the form the most complicated of the genus.

Near the anterior margin of the head and well in front of the mouth occurs transverse band 1 (Fig. 15, I), which in the type specimen consisted of a broader dorsal and narrower ventral half meeting laterally in a sharp posteriorly directed angle. From band 1 there extends a mid-dorsal line the whole length of the body. A short distance behind the neck[1] occurs band 2, which is broad and distinct, but interrupted laterally whence proceed caudad *two-paired lateral lines.* These extend the whole length of the body. A mid-ventral line also commences from band 2, arising from a flecked area involving the lower laterals.

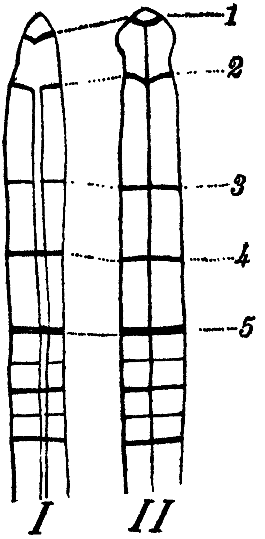

FIG. 15. *Carinella sexlineata* n. sp. I. Lateral. II Dorsal aspect. Drawn from alcoholic specimens.

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[1] Neck = constriction separating head from rest of body.

The mouth is situated between bands 1 and 2 and in type specimen did not pierce band 2 (difference from *C. superba*). At intervals much greater than between 1 and 2 occur bands 3, 4 and 5, with no intermediate annulations. Band 3 is the broadest, its edges fimbriated, and interrupted between the laterals; 4 and 5 are more sharply outlined, 4 continuous, 5 partially interrupted at the laterals by the side organs (difference from both *C. superba* and *C. annulata*, in neither of which do the side organs occur on a transverse band). The broken mid-ventral line continues nearly to band 5, where it breaks up into a row of fine dots which may be sometimes traced along the rest of the body. From band 5 to posterior extremity of body occur broad uninterrupted annulations sometimes double, placed some distance apart, with one to three finer intervening annulations, which are interrupted or nearly so at the laterals. The intervals between these body annulations are nearly equal.

VARIATIONS. It must be noted on behalf of the validity of this species that the above outlined pattern is in its main features remarkably constant. The variations, so far as was observed, involve merely the shade of the ground color, the amount of flecking, the *composition* (*i. e.*, whether full or broken) and extension of the lines. The few specimens obtained near Sitka, Alaska, were darker in color, with much less flecking and fimbriation of the annulations. Those taken about Puget Sound showed considerable flecking on the head behind band 1 and on dorsum, mostly near lines or bands. Moreover, in some specimens the lines are more continuous, in others more or less dotted or broken.

In alcohol the worm darkens considerably, but even then the main pattern can be easily made out. The side-organs then appear as white circular spots.

INTERNAL ANATOMY. A cephalic gland is absent as in *C. superba*. Differs from latter in general absence in region of side organ of a pronounced dorsal and ventral decussation of the circular muscles of the body-wall. A fine raphé of connective tissue is generally present in its place, which may involve a few muscle-fibers. In one individual sectioned these were so abundant as to produce a decussation similar to *C. superba.* The variation of this structure would appear to show that but little reliance can be placed upon it for specific determinations. A layer of longitudinal muscle fibres separates the œsophagus from the circular muscles of the rhynchocœlom as in *C. rubicunda.* Cephalic organs consist of a paired ciliated tube which penetrates the epithelium to end blindly next the basal membrane. Nephridia consist of branching tubules, portions of which bulge more or less into the lateral vessels. They open at their posterior extremity by a pore above the side organs, *i. e.*, in transverse band 5.

Habitat and Distribution. Dredged in Kilisut Harbor opposite Port Townsend, in from 3 to 4 fathoms, also taken under bark of wharf-piles in its tough hyaline tube, as well as in the sand between tides. Likewise taken in and about Sitka Harbor, Alaska.

This worm grows to a great length; some incomplete fragments when fully extended were over a meter in length.

2. **Carinella rubra** n. sp.

? *C. miniata* Hubrecht.[1]

Color in life a uniform bright red. In alcohol the pigment quickly washes out, leaving the worm a dull gray. The mature worm reaches an enormous length, some of the smaller individuals (incomplete) measuring over 140 cms., while the largest observed must have been at least two meters in length.

Internal Anatomy. Well developed glands fill the head (differences from *C. polymorpha*). Cephalic organs are epithelial pits which do not reach the basal membrane. Dorsal and ventral decussation of circular muscles absent or very weak.

Habitat and Distribution. Taken in sand and silt between tides at Puget Sound (Bremerton), Kilisut Harbor, and Sitka, Alaska.

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[1] Bürger ('95) figures a red species (*C. miniata* Hubrecht) which may possibly be identical with this species, but since no sections were obtained its identity with *C. rubra* can be but a matter of conjecture. In color, size and form of head they differ not a little. In form and size *C. rubra* more nearly resembles *C. polymorpha.*

MESONEMERTINI.

3. **Carinoma mutabilis** n. sp.

Color a pure creamy or milky white, with faint cloudy mottlings in intestinal region, which cease a short distance from the posterior extremity, leaving the tail region pure white.

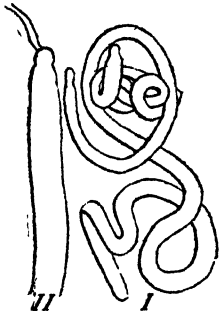

FIG. 16. *Carinoma mutabilis* n. sp. I. Two individuals of type. II. variety *argillina*. Camera lucida from alcoholic material.

Length and breadth variable, the largest individuals of the type measured 14 cms. by 1 mm. in alcohol.

Head hemispherical, narrower than body and marked off from latter by a slight narrowing or neck. No eyes or caudal cirrus.

INTERNAL ANATOMY. This species approaches very closely the *C. patagonica* Bürger ('95). It appears to differ, however, in several particulars, especially in size and in the disposition of the nephridial tubules. The latter are large and loosely ramified, but three or four cross sections of them appear in each section and, although some of the branches are situated close to the blood vessels, they do not appear to bulge into them to the extent that they do in *C. patagonica.* They open to the exterior by a single-paired excretory pore, the position of which varies in different varieties, though always dorsal to the nerve-cords. Circulatory system in its main features as in *C. patagonica.* Ventro-lateral blood vessels thick-walled, thickness of which steadily increases as nephridial region is reached. This peculiarity can be traced throughout the nephridial region.[1] Dorso-lateral vessels thin-walled throughout. Dorsal and ventral nerves anteriorly outside the outer circular muscle-layer. A double diagonal muscle-layer commences to appear in the anterior œsophageal region.

Inner circular-muscle-layer much thicker anteriorly than in *C. patagonica.*

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[1] Compare similar phenomenon figured by McIntosh ('75).

Just in front of the nephridial region the following changes occur:

1°. Inner circular-muscle-layer becomes enormously thickened.

2°. Dorsal and ventral nerves commence to break through the outer circular-muscle-layer and dip down toward the inner layer.

3°. Lateral nerve cords commence to break away from the inner side of the outer circular-muscle-layer and sink deeper into the longitudinal layer.

4°. Diagonal muscles commence to thin out, to disappear completely a short distance further back.

Proboscis-pore subterminal, cephalic lacunæ extend to tip of head. A cephalic gland is present in type specimen. It consists of deeply staining lobules that hang into the cephalic lacunæ anterior to the proboscis pore.[1] Brain, with lacunæ and rhynchocœlom in brain region, more or less completely inclosed in an inner capsule of connective tissue separated from basal membrane by a thin longitudinal muscle-layer. Mesenchyme scanty.

Habitat and Distribution. In sand between tides and on piles of wharves, along the west shore of Port Townsend harbor, between the wharves of the city and the railroad depot.

Two varieties of this species were taken, which for convenience of reference will be distinguished by varietal names.

4. **Carinoma mutabilis argillina** n. var.

General form and color as in type. The entire worm was not obtained; the largest fragment measures 15 cms. by 3 mm. in alcohol. Differs from type in larger size, rather more powerful muscular development. Excretory pore in œsophageal region where inner circular-muscle-layer is still thick, and anterior to cessation of dorso-lateral vessels, *i. e.*, slightly further cephalad than in type. Mesenchyme rather more extensive, lateral halves meeting in mid-ventral line behind mouth.

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[1] Bürger ('95(1)) makes no reference to a cephalic gland in *C. patagonica*, and ('95(2)) is not quite sure of its presence in *C. armandi*.

HABITAT AND DISTRIBUTION. Between tides in hard blue clay among pholads, not apparently in burrows of latter, but in surrounding clay, to all appearances excavating burrows of its own.[1] Locality, west of Point Wilson on shore of Strait of Juan de Fuca.

5. **Carinoma mutabilis vasculosa** n. var.

Form and color as in type, size intermediate between type and var. *argillina*. Mesenchyme most extensive, in œsophageal region nearly surrounding the very large blood vessels. Ventrolateral vessels branch from time to time. Excretory pore at commencement of visceral region where inner circular-muscles thin out.

HABITAT AND DISTRIBUTION as in type, except that it was not taken on piles.

All these varieties build sand-tubes and in mode of life resemble somewhat *Cerebratulus*, though they do not swim nor readily fragment themselves as do the cerebratulids, and appear generally more sluggish.

ANALYTICAL KEY TO SPECIES OF CARINOMA.

A.—Nerve cords anteriorly without circular muscle layer; further back they break through the latter, and lie wholly within longitudinal layer.............................**C. armandi** (McIntosh) Oudemans.

B.—Nerve cords wholly within longitudinal layer throughout their entire course.

a—Small (3.5 cms.). Brain free in longitudinal muscles of head. Nephridia bulge far into thin-walled blood vessels. Dorsal and ventral nerves wholly within outer circular-muscles-layer throughout their entire course...**C. patagonica** Bürger.

β—Large (14–15 cms.). Brain enclosed in connective tissue capsule. Nephridia do not bulge so far into the thick-walled blood vessels. Dorsal and ventral nerves anteriorly without outer circular-muscle-layer; further back break through same...**C. mutabilis** Mihi.

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[1] If this be true, the fact is interesting because of the soft-bodied nature of the animal. The annelid *Halla* ? is known to bore in the till (Harrington and Griffin, '96), but this animal, unlike the Nemertean, has powerful jaws and a firm exoskeleton. Heretofore no Nemertean has been known to bore in so hard a substance (McIntosh, '68).

METANENMERTINI.

6. **Emplectonema** Stimpson, 1857.

1873 *Nemertes* McIntosh (*nec* Cuvier 1817).
1873 *Macronemertes* Verrill.
1890 *Eunemertes* Vaillant.

This genus is defined by Stimpson as follows: "Corpus longissimum subfiliforme, depressum, proteum. Caput subdiscretum, stricturis nullis, fovea longitudinali in utroque margine antero-laterali. Ocelli plurimi." Later writers (including McIntosh, Vaillant, and Bürger) have added the following anatomical characters to the definition. Mouth opens into the rhynchodeum; proboscis very short; rhynchocœlom restricted to anterior third of body; cerebral organs very small and far in front of brain; head gland but rarely reaches to brain.

7. **Emplectonema viride** Stimpson, 1857.

Stimpson gives the following description of this species in his *Prodromus*: "Corpus depressum, lineare v. proteum, supra viride, subtis album. Caput subdiscretum, marginibus albis; foveis elongatis bipartitis; fronte emarginata. Ocellorum acervi quattuor; posteriores distincti, rotundati, ocellis confertis; anteriores marginales juxta foveas, occellis sparsis. Long. 11 lat. 0.05 poll. Hab. in portu 'San Francisco' littoralis inter lapillos."

The form here referred to *E. viride* occurs widely distributed from Puget Sound to Alaska, and shows no local variations, the same varieties being found in all localities visited. As a general rule, however, the specimens from the more northern latitudes are darker in hue.

Length of largest specimen nearly 1 m., breadth 1–2 mm., head spatulate, emarginate in front, not especially marked off from body, not wider than body.

Three color varieties are common: (1) A slender and smaller form, very light olive green, (2) a much darker green form which shows on head and anterior portion of body, a mid-dorsal longitudinal line, and one transverse band at neck (fig. 17, (3), a form almost black and not showing the lines that characterize No. 2. All three varieties agree in the much lighter ventral portion marked off from darker dorsum by sharp line of demarkation. Anterior and lateral margins of head in all three varieties very light almost white. Eyes numerous, distributed along side of head, on each side of demarkation-line between light margin and dark dorsum. The colors keep fairly well in alcohol, darkest green, paler, palest olive, and even bluish varieties can be distinguished. Some specimens from West Berkeley, California, became gray in alcohol.

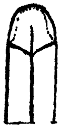

FIG. 17. *Emplectonema viride* Stimpson. Showing pattern on head.

INTERNAL ANATOMY very similar to *E. gracile*. Mouth opens into rhynchodeum; cephalic organs some distance in front of brain; canals from cephalic organs run forward to open ventrally in region of proboscis-pore; proboscis-pore[1] some distance from tip of head.

Intestinal cæca do not quite extend to brain. Central stylet of proboscis with very long basal portion, two marginal stylet-pockets are present, each containing five long curved stylets. Ducts from these marginal pockets appear to be dilatable proximally (fig. 18). In some specimens preserved in alcohol the stylet gland and basal portion of central stylet are a bluish green in color and contrast strongly with the adjoining non-pigmented portion of the proboscis.

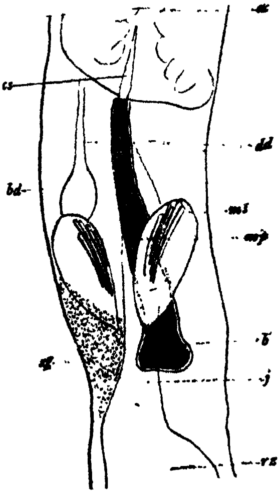

FIG. 18. *Emplectonema viride.* Stylet and region of proboscis. *ac.*—anterior chamber. *cs.*—Central stylet. *dd.*—ducts of marginal pockets. *bd.*—basal dilation of same. *ms.*—marginal stylets. *mp.*—marginal pockets. *b.*—basal portion of central stylet. *f.*—ejaculatory duct. *sg.*—stylet gland. *rs.*—reservoir.

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[1] In instances like this where the mouth opens into the rhynchodeum the common opening ("gemeinschaftliche Oeffnung" Bürger) will be called proboscis-pore.

This species very strikingly resembles *E. gracile* Johnston. It may be distinguished by its narrower head with sharply defined color patterns and general darker hue of body.

HABITAT AND DISTRIBUTION. Taken on piles, on and under stones at Port Townsend, Washington ; Fort Wrangle and Sitka, Alaska. The type locality (Stimpson) is the bay of San Francisco. Its range, as so far determined, is then from San Francisco to Sitka.

8. **Emplectonema violaceum** Bürger, 1896.

Eunemertes violaceæ Bürger.

In life this form secretes an enormous amount of slime in which it lies coiled up in tangled knots. It was found next to impossible to straighten it out sufficiently for accurate measurement, but its length was estimated to be at least 50 cms. Broken fragments in alcohol measure over 30 cms. Shape extremely flattened, ribbon-like. Head rounded in front, directly continuous with body. Color varies somewhat, though a fairly constant pattern is presented on dorsum, which is densely flecked with purple or brown upon a pale yellowish brown ground color. Ventral portion yellowish white. Eyes numerous.

THE INTERNAL ANATOMY agrees more or less closely with Bürger's ('96) description. It "does not possess a powerfully developed head gland. The cerebral organs are very small and lie very far in front of the brain. Many small eyes are present. The œsophagus opens into the rhynchodeum." Powerfully developed integumentary glands are present throughout the body.

HABITAT AND DISTRIBUTION. On piles about Port Townsend, coiled in a tangled mass, and enveloped in its mucus. The type specimens of Bürger were obtained near Calbuco, on the coast of Chile. Its range is thus quite extensive.

The great amount and tenacity of the slime proves an obstacle to its proper preservation, as a coagulation of the slime apparently hinders the thorough penetration of the alcohol.

9. **Amphiporus imparispinosus** n. sp.

Length in alcohol, 40–45 mm. Breadth, 1–2 mm. Color, white. Head in extension hemispherical, broader than body. Eyes numerous (23 ± on each side), distributed in two elongated concentric groups along antero lateral to lateral margin of head, not extending behind brain as in *Zygonemertes virescens* (Verrill) (fig. 19). Body widest anteriorly, tapering off to a slender posterior extremity.

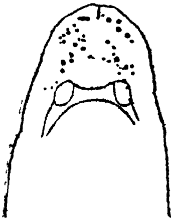

FIG. 19. *Amphiporus imparispinosus* n. sp. Camera lucida, from living worm under influence of chloral hydrate and compressed under cover slip.

INTERNAL ANATOMY. Mouth opens into rhynchodeum. Cephalic gland not prominent. Cephalic commissure[1] above proboscis-pore. Cephalic organs in front of brain, dorso-lateral to ventral ganglia, opposite mouth ; the canals open ventrally just behind proboscis-pore. Nephridia commence behind brain and open to exterior by numerous efferent ducts, just dorsal to nerve-cords. Nephridia cease just behind 2d or 3d pair of gonads. Intestinal cæca extend to brain. Apparently no integumentary glands in body. Rhynchocœlom does not extend quite to posterior extremity. Central stylet as long as basal portion, latter constricted in middle (fig. 20). Three marginal-stylet-pockets, each containing two stylets.

This species is apparently to be distinguished from *A. dubius* Hubrecht, by its numerous eyes and paler color, and from *A. Greenmanni* Montgomery, by its larger size, greater number of eyes and distribution of eyes and color of body.

HABITAT AND DISTRIBUTION. On piles and stones, Port Townsend and Sitka.

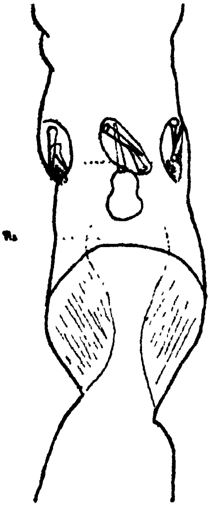

FIG. 20. *Amphiporus imparipinosus* n. sp. Stylet region of proboscis. Camera lucida from total preparation. *Rs.* reservoir.

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[1] By cephalic commissure is here meant that connecting the blood vessels anteriorly.

10. **Amphiporus formidabilis** n. sp.

Length in alcohol 9 + cms. Breadth 2 mm. Form and color as in preceding species except for flesh-colored tinge anteriorly. Visceral region dull gray. Eyes very numerous (100–150±), distributed in three groups, one antero-lateral paired group and one median unpaired group. The latter is V-shaped and situated just in front of brain, with the limbs directed backwards and merging into two gray streaks that extend along each side for a varying distance caudad (fig. 22).

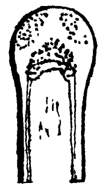

FIG. 21. *Amphiporus formidabilis.* Free-hand from living worm.

INTERNAL ANATOMY. Mouth opens into rhynchodeum. Head densely packed with cells of cephalic gland. Cephalic commissure just posterior to proboscis-pore. Cephalic organs in front of brain, opposite mouth, canals open laterally behind proboscis-pore. Intestinal cæca extend to brain. Nephridia open by numerous efferent ducts, some of which open dorsally, others laterally. Integumentary glands abundant in anterior portion of body. Rhynchocœl extends to end of body.

Central stylet shorter than its basal portion. Marginal stylet-pockets arranged in a continuous row around the central stylet. Their number appears to be either 8 ± or 12 ±. Each contains two stylets.

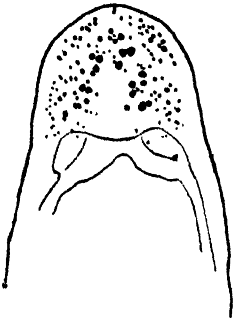

FIG. 22. *Amphiporus formidabilis.* Camera lucida from worm under influence of chloral hydrate under cover-slip.

In number and arrangement of the marginal stylet-pockets this form bears close resemblance to *A. spinosissimus* Bürger and *A. pugnax* Hubrecht, but differs in numerous anatomical points from *A. spinosissimus*, especially in the position of the excretory pores.

HABITAT AND DISTRIBUTION. On piles of wharves, and on stones and rocks along with *A. imparispinosus* and *Emplectonema viride.* Puget Sound and Alaska.

11. Amphiporus brunneus n. sp.

Length in alcohol of largest individual 3.3 cms. Breadth 5 mms. Color (in life) dark brown or smoky black on dorsum, greenish or yellowish white ventrally. On each side of neck is a pale angular spot.

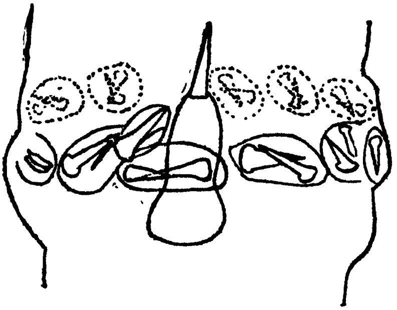

FIG 23. *Amphiporus formidabilis* n. sp. Stylet region of proboscis. The dotted pockets and stylets filled in diagrammatically, the rest from camera lucida drawing.

INTERNAL ANATOMY. Proboscis-pore subterminal. Cephalic gland moderately developed. Cephalic organ considerably in front of brain. Cephalic canals open opposite mouth. Intestinal cæca extend almost to brain. Anterior portion of proboscis very long; in ordinary protrusion the stylet-region remains within the everted anterior chamber. Basal portion of central stylet long, two marginal pockets each containing two (or three ?) stylets.[1]

HABITAT AND DISTRIBUTION. On piles and rocks about Port Townsend.

12. Amphiporus angulatus (Fabr.) Verrill ?

I have provisionally referred to this species a form that occurs (though not very abundantly) under stones near lowest low water mark in Sitka Harbor, Alaska. But two alcoholic specimens are now available for description.[2] It readily contracts into a thick oblong mass.

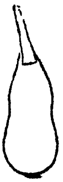

FIG. 24. *Amphiporus brunneus*. Central stylet. Camera lucida.

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[1] Rhynchocœl surrounded by a thin circular muscle sheath, within which is a layer of longitudinal muscles.

[2] Owing to these two specimens having been collected too late to be packed with the rest of the Alaska material, they were placed in the writer's microscope case, and were therefore saved when the ship went down.

Length in alcohol, 4–7 cms. Breadth, 5–6 mms. Color (in life) a reddish purple on dorsum, white ventrally. Head with prominent marginal white spots at neck.

INTERNAL ANATOMY. Cephalic gland fairly well developed; proboscis-pore sub-terminal and anterior to cephalic commissure. Cephalic canals enter ventrally and run caudad for some distance in the epithelium. In the region of the mouth they break through the circular muscles to reach the cephalic organs.[1]

Cephalic organs large, considerably in front of brain. Mouth opens into rhynchodeum. Dorsal commissure fairly large. Intestinal cæca short, do not extend near to brain. Anteriorly the integumentary glands are very abundant ventrally, sparsely distributed dorsally. Rhynchocœl surrounded by thin sheath of outer circular and inner longitudinal muscles. In visceral region gonidial pockets are numerous; a single section shows several, distributed dorsally and laterally to the intestine.

HABITAT AND DISTRIBUTION. Under stones near lowest low water mark. Sitka Harbor and Redout Bay, Alaska.

Besides *A. brunneus* there are several other forms that bear a more or less general resemblance to *A. angulatus*, and are to be classed among the boreal species. Stimpson's *Cosmocephala Beringianus* and *C. Japonicus* are both believed by Verrill ('92) to be varieties of *A. angulatus.* At Sitka the present writer obtained three quite similar forms (sizes quite different) which seem to approach *A. angulatus.* When studied under a lens they were seen to possess two paired white lines between which, in two of the forms, the cervical white patches were situated, so characteristic of *A. angulatus.* In the third these angular patches seem to have been absent or represented by a faint paling of the ground color. Each of the three, with *A. angulatus* seemed to characterize a particular zone of the beach between high and low water mark.

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[1] The one specimen sectioned showed an interesting abnormality in the cephalic canal and organ of one side (left?). On this side the cephalic organ lay much further caudad so as to be opposite to the ventral commissure, while its canal forked in the epithelium, one branch opening dorsally, the other more ventrally. The cephalic organ of the right side lay considerably in front of brain.

13. **Amphiporus drepanophoroides** n. sp.

Color red above, white below. Length probably not over 4–5 cms. Form short and stout. Eyes numerous in rows along antero-lateral margin of head.

INTERNAL ANATOMY. Proboscis-pore terminal. Cephalic gland prominent. Integumentary glands also prominent in head, all situated ventrally and ventro-laterally. Further back they commence to thin out (at first in the mid-ventral line) and disappear completely a short distance behind brain. Mouth opens into rhynchodeum. Cephalic organs large, anterior portion opposite ventral commissure, closely pressed against brain, further back they become pushed in between dorsal and ventral ganglia and extend back of dorsal ganglia. Their canals open laterally in front of ventral commissure. Differs from all the preceding Amphiporids in the smallness of the rhynchocœl, and in having the latter enclosed in a thick muscular sheath in which longitudinal and circular muscles are interwoven. No forwardly extending intestinal cæca. Circular muscle-layer quite thick.

HETERONEMERTINI.

14. **Lineus striatus** n. sp.

Owing to loss of all color notes and drawings by shipwreck, no *detailed* description can be here given of its appearance during life.

Color brownish red on dorsum, sharply marked off laterally from the much lighter ventral portion. Dorsum marked by numerous creamy white transverse bands which cease at the demarkation-line between the dorsal and ventral coloring. Tip of head brilliant red. Length probably not over 4 cms.

This form seems from the above quite similar to *Micrura fasciolata*, yet it is at most but one-half the size of the latter, much flatter, the pattern much sharper and constant, and in all specimens obtained no cirrus was present. For these reasons it must at present be referred to *Lineus*.

INTERNAL ANATOMY. Nephridial system with numerous efferent ducts opening dorsally to the nerve cords. In one section two ducts occurred, one slightly dorsal to the other.

HABITAT AND DISTRIBUTION. Under stones and in sand between tides, Kilisut Harbor, and Bremerton. Not taken in Alaska.

15. **Lineus** sp. —.

This species, which appears to be new, was found among a mass of hydroids that had been preserved in formalin. The single specimen measured 5.2 cms. by 5 mms.; it was an entire worm. Color smoky black with greenish tinge on dorsum, gray-brown ventrally.

INTERNAL ANATOMY. Cutis richly supplied with gland cells of which two kinds occur, one staining with hæmatoxylin, the other with congo-red. In this respect the cutis is similar to the epithelium.

HABITAT AND DISTRIBUTION. Among hydroids (*Diphasia*) about Port Townsend.

16. **Cerebratulus marginatus** Renier.

I have referred to this species a smoky black form that occurs abundantly in the sand between tides at Port Townsend and Bremerton. Most of the specimens differed from the Neapolitan form figured in Bürger's monograph, in lacking the white coloration on the posterior extremity, and the white rims to the cephalic furrows. As the specimens showed variation in this regard, some approaching quite closely the typical form, and as the internal anatomy is indistinguishable from that of specimens from Naples, I have referred this form to *C. marginatus*.

17. **Cerebratulus** sp.

Portions of a very large dark form with flesh-colored lateral margins were obtained. Some of the fragments in alcohol measure nearly 20 mms. in diameter. In internal anatomy it seems to approach *C. marginatus*; the only noticeable point of difference appears to be that the cephalic slits cease at least

10 sections (each cut at least 30 μ thick) in front of mouth. In *C. marginatus* they cease in the section in which the mouth commences.

IV. SUMMARY.

Of the fourteen species treated in the foregoing; nine appear to be new and peculiar to the Pacific coast of North America; two (*Emplectonema viride* and *E. violaceum*) are already described, although likewise peculiar to the west American coast; one (*Amphiporus angulatus*) with three problematical forms are boreal and are represented on the north Atlantic coast, and one (*Cerebratulus marginatus*) is cosmopolitan. Among the forms peculiar to the west coast are a few that show remarkably close resemblance to west European forms. Thus *Carinella sexlineata* is the Pacific representative of *C. superba*, while *C. rubra* resembles *C. miniata*. *Emplectonema viride* is very closely similar to *E. gracile*. *Lineus striata* resembles *Micrura fasciolata*.[1] Another conspicuous fact is the complete absence of Atlantic American species, outside of the strictly boreal forms such as *Amphiporus angulatus*. No banded Carinellas occur on the east coast[2], no *Carinoma* has as yet been found. The east coast Amphiporids and Lineids are either unrepresented on the Pacific or replaced by different species. The noticeable scarcity of *Lineus* on the west coast is perhaps to be correlated with the superabundance of different forms of *Amphiporus*, which apparently replace them functionally.

Zoölogical Laboratory of Columbia University,
March, 1898.

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[1] If it can ever be shown that *L. striata* actually does possess the cirrus, and hence is a micruran, this parallel will be further strengthened.

[2] Except the "large Canadian *Carinella* dredged in the Gulf of St. Lawrence by Mr. Whiteaves." McIntosh '75.

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[ANNALS N. Y. ACAD. SCI., XI, No. 11, pp. 219 to 223, August 13, 1898.]

AN IMPORTANT INSTANCE OF INSECT COALESCENCE.

HENRY E. CRAMPTON, JR.

(Read March 14, 1898.)

DURING the winter of 1896–97 the writer performed a number of experiments upon lepidopterous pupæ, in order to ascertain if it were possible to produce a coalescence between two individuals, or parts of individuals, similar to that obtained by Born with the embryos of Amphibia. A report upon the results of these experiments is embodied in the form of a Woods Holl lecture for 1897. Without going into details, it might be stated that the two main problems were: first, whether "grafting," or the production of coalescence, were possible with lepidoptera; and second, if such coalescence could be brought about, whether the colors of one moth could be made to replace those of another by a transfusion of hæmolymph. The first point was determined successfully in about twenty cases out of nearly two hundred experiments. The second point remained undetermined on account of the small number of successful cases. During the present winter, in the course of a further series of experiments, numbering at present over 750, one specimen was obtained which exhibited conditions of exceptional interest. It is considered worthy of a special notice, as the full account of the winter's experiments cannot of necessity be published for some time.

The case in question (No. 341) consists of a *Callosamia promethea*, united "in tandem" anteriorly to a *Samia cecropia*. In an operation of this kind part of the abdomen of the anterior component is cut away by a transverse section back of the wing-cases, *i. e.*, between the fourth and fifth abdominal segments; the remainder of the pupa is united to a posterior component which has been deprived by a transverse section of its anterior part, namely, head, prothorax and the basal parts of the limb, mouth-part and antenna sacs. The method of keeping the parts together, by means of melted paraffine applied to the edge of the common wound, has already been described in a communication before this section of the Academy at a meeting. last spring. The condition of the pupæ was quite advanced, owing to their being kept in the warm laboratory from the time they were procured in November. But, as is often the case, one of them, the *cecropia*, was more advanced than the other, and was, indeed, ready to emerge fully five days before the *promethea*. Only the posterior portion of the pupal case of the former was removed to permit of the voidance of excreta. When the *promethea* was ready to emerge its pupal case and the remainder of that of the *cecropia* were removed. The compound was supported below a ball of cotton, so that the moths could hang suspended from it, and thus assume the attitude which is almost indispensable for the expansion of the wings. Nevertheless, in spite of all arrangements, the wings of neither component expanded, and the colors, therefore, appear on a reduced scale. The wings of the *cecropia* remained soft and evidently in a diseased discolored condition, owing, no doubt, to the prolonged enforced stay in the pupal cases.

The general appearance of the complex is that of a long body, provided with two sets of wings and legs. The facts of special interest are: first, those of the structural conditions; and second, those relating to the coloration; for, although the *cecropia* wings show no abnormalities aside from their general decomposed condition, the wings of the *promethea* exhibit some most remarkable appearances.

First, the structural peculiarities will be noted. These occur naturally at the region of union between the two components. From the *cecropia* were cut away the head, prothorax and mesothorax in part, and as well the basal parts of the antenna and palp sacs, and those of the first pair of legs. These parts are all absent in the metamorphosed complex. In dorsal view the fourth abdominal segment of the *promethea* is united to the remains of the mesothorax of the *cecropia* by a sheet of regenerated tissue which is exactly similar to the hairless bands connecting normal abdominal segments. On the ventral side a more complicated condition appears. There is, of course, the sheet of regenerated tissue which unites the fourth abdominal segment of the *promethea* to the thorax of the *cecropia.* To this sheet of tissue are attached the bases of the coxæ of the first pair of legs, and the femoro-tibial joint of the right one as well. The second and third pairs of legs and the wings arise normally in their proper places. The antennæ and palps are absent in this specimen owing to the application of paraffine over the sacs, thus blocking them off.

It is obvious that this condition has been brought about as follows : the growing edges of the opened leg-sacs, in regeneration naturally grew fast to whatever tissue extended over them. This tissue was the regenerated band connecting the bodies of the two components. Development proceeded normally, each part completing itself as usual, and presenting in the freed complex the above condition. The reason why the knee of one limb is also fused is evident when we consider the doubled-up nature of the leg-sac. The knee had been involved in the slightly oblique section.

The color-conditions are by far the most interesting. The *cecropia,* as far as can be determined, possesses the normal specific colors. Portions of the *promethea* wings, however, *present the colors characteristic of only the wings of cecropia.*

The *promethea,* it will be remembered, was a female. In addition to the pupal diagnostic character—the relatively smaller size of the antennæ—the imago was cut open, and eggs were taken from the body, so that no doubt remains as to the sex. There are but few traces in the imaginal wings of the characteristic red-brown of this sex. In detail the colors are as follows : the upper surfaces of the anterior wings are mixed, buff and slate. Upon magnification, the scales are seen to contain only these pigments. There are few containing the characteristic reds and browns of a typical *promethea* wing. There is about the center of the wing a patch of bright red scales similar in every way to the patches upon a *cecropia* wing, and differing from anything normal upon a *promethea* wing. The upper surfaces of the posterior wings show also the mixed slate and buff colors. There are no reds or browns, and there is no inner red line to the dark border of the wing. Below, the anterior wings have the anterior portion reddish, the middle part blackish, and posterior part red, thus differing not markedly from the normal. The posterior wings below are reddish, although with a mixture of buff quite similar to the corresponding normal *promethea* wing. The body hairs are a deep reddish purple, again a nearly normal color.

From these details it will be seen that while the body and the lower surfaces of the wings present a nearly normal appearance, or at least a condition within the possible limits of specific variation, nevertheless the upper surfaces of the wings present a very great departure from the normal, and resemble very closely the colors of a normal *cecropia* wing. The latter colors are apparently outside the bounds of possible variation within the species. And as the body cavity of the *cecropia* component lies in this case in open communication with the body cavity of the *promethea*, and thus to the wings, it may be inferred, I think, that the colors in the wings of the *promethea* which resemble the normal *cecropia* colors were produced by the presence and decomposition of *cecropia* hæmolymph where such colors appear in the *promethea* wings.

This experimental production of a transfusion of hæmolymph, and subsequent color-effect of one moth upon another, is a striking case in support of the conclusions arrived at by A. G. Mayer from a study of normal phenomena. To the work of Mayer, and to a lesser degree of some others, we owe our knowledge that the pigmental colors of *Lepidoptera* are produced by the chemical decomposition of the hæmolymph in the empty scale cells. In this case the relatively small amount of *promethea* hæmolymph was without any effect upon the *cecropia*; while the more abundant hæmolymph of the *cecropia* entering the body of the *promethea* produced, by its presence and disintegration, the colors of the *cecropia* in portions of the wings of the *promethea*.

The above conclusion receives considerable support, and, in point of fact, confirmation from the results of certain other experiments. In several cases, where a small part of the moth has been united to a much larger part, the former takes on, in the imago, the characteristic colors of the major part. One very striking case in point is one obtained recently. The head and prothorax, with other minor parts of a *polyphemus* pupa, having been removed, the corresponding parts of a *cecropia* were supplied. The resulting metamorphosed imago exhibits an apparently perfect insect. The hairs of the head and thorax derived from the *cecropia,* however, show no trace of the *cecropia* color, but are shiny buff, the color of the corresponding parts of a *polyphemus.* The available hæmolymph was, of course, only that of the *polyphemus* body, and therefore the colors were those characteristic of that species.

The foregoing account, reinforced by the other minor results above mentioned, goes to show, I believe, that it is possible *in some cases* to produce a definite color-effect of one moth upon another, by producing a coalescence between them, thus permitting a transfusion of hæmolymph. Why this reciprocal color-effect obtains in some cases, but not in others, now becomes the next problem to be investigated.

COLUMBIA UNIVERSITY.

[ANNALS N. Y. ACAD. SCI., XI, No. 12, pp. 225 to 258, August 13, 1898.]

THE NORTHROP COLLECTION OF CRUSTACEA FROM THE BAHAMAS.

W. M. RANKIN.

[PLATES XXIX–XXX.]

THE Crustacea collected by Professor and Mrs. Northrop in the Bahama Islands in 1890 were sent to me by Professor Osborn, with the request that I prepare a report on them. The following list is the result. Such a list is of necessity largely a mere catalogue of names, but it is hoped that it may be of service in the preparation of a more extensive fauna of the Bahamas when such a work shall be undertaken. It has been with the idea of giving a little wider interest to the list that with each species the range of distribution has been given, and also the West Indian Islands noted where the species has been found, although this latter record is no doubt incomplete. I hope at least these notes of distribution may serve as a suggestion for the fuller record of the distribution of these species among the West Indies. The synonymy I have made brief, merely citing the original author and usually a reference to the work where a complete synonymy may be found.

The letters (*a*), (*b*), etc., in many species indicate the various series of specimens in the collection as they were arranged originally or, in some cases, sorted out by me after their receipt. To these series I have fortunately been able to add some notes made by Professor Northrop when the collections were made, and recently sent me by Mrs. Northrop.

Among the sixty-seven species collected I have determined four as new species and one I have ranked as a new variety. There is also published for the first time a figure of *Stenopus lævis*. For the careful drawings of the figures I am indebted to Mr. R. Weber. I wish to express my obligations to Miss Rathbun, of the National Museum, for assistance in identifying a few species; and also to Dr. Ortmann, of Princeton, who has kindly assisted me in many ways and to whom this report owes much of any value it may possess.

DECAPODA.

BRACHYURA-CATOMETOPA.

Family **Ocypodidæ** Ortmann.

1. **Ocypode arenaria** (Catesby).

Cancer arenarius Catesby, History of the Carolinas, II, p. 35, 1771.

Kingsley, Proc. Acad. Nat. Sci., Phil., 1880, p. 184.

Ortmann, Zoöl. Jahrb., VII, p. 765, 1894.

(*a*) 5 ♂, 2 ♀. Near Nassau, N. P., Jan. 24, '90.

Range: South shore Long Island to Rio Janeiro.

Collected at Cuba, Jamaica, St. Thomas, New Providence.

2. **Uca platydactyla** (Milne-Edwards).

Gelasimus platydactylus Milne-Edwards, Hist. des Crustacés, II, p. 51, 1837.

G. heterocheles Kingsley, l. c., 1880, p. 137.

(*a*) 4 ♂. Under sides of stones, Dix Point, near Nassau, N. P., Feb. 4, '90.

(*b*) 8 ♂, 7 ♀.

Range: East and west coasts Central America, West Indies.

Collected at Jamaica.

3. **Uca vocator** (Herbst).

Cancer vocator Herbst. Natur. Krabben u. Krebse, III, pt. IV, 1804.

Gelasimus vocator Martens; Kingsley, l. c., 1880, p. 147.

(*a*) 1 ♂. Bahama Islands.

Range: East coast of America, west coast of Mexico, Panama, West Indies.

Collected at Bahamas, Cuba, Hayti, Jamaica.

4. **Uca stenodactyla** (M. Edwards et Lucas).

Gelasimus stenodactylus, M. Edwards et Lucas in D'Orbigny's Voyage, 1843.

Kingsley: l. c., 1880, p. 154. Ortmann: l. c., p. 760, 1894.

(*a*) 1 ♂. Common in mud on west side of Andros Island, near Red Cays, Apr. 17, '90.

Range: West Indies, Central America, East and West Coasts. Collected at Cuba.

5. **Uca leptodactyla** (Guérin MS.).

Gelasimus leptodactylus Guérin MS. (types in Phila. Acad.).

Gelasimus stenodactylus Kingsley, Proc. Acad. Nat. Sci., Phila., p. 155 (part), 1880.

(*a*) 10 ♂, 5 ♀. Holes in sand between tides about 5–6 in. deep, very shy, near Ft. Montagu, Nassau, N. P., Jan. 28, '90.

Some of these specimens were sent to the United States National Museum, where they were identified by Miss Rathbun, and to whom I am indebted for the following note of description:

"*Uca leptodactyla* belongs to the division of the genus in which the front between the eyes is broad and the body is short, broad and subcylindrical. It is most nearly related to *U. stenodactyla*; the chief differences are as follows: In *U. stenodactyla* the body is much higher than in *leptodactyla*, being usually higher than long. The anterior margin of the carapace from the base of the eyestalk to the antero-lateral angle is much more oblique in *leptodactyla*, and the lateral margins are much more convergent posteriorly. The carapace of *leptodactyla* is, therefore, more pentagonal than that of *stenodactyla*. In *stenodactyla* the lateral margin is much dilated behind the antero-lateral tooth, which is not the case in *leptodactyla*. The inner surface of the hands differs as follows: The short ridge on the palm at the base of the dactylus is perpendicular to the base of the propodos in *leptodactyla*; while it is oblique in *stenodactyla*. In both species the tubercular ridge running obliquely upward from the lower margin makes an angular turn at the middle of the inner surfaces, and is continued until near the upper margin. In *leptodactyla* this continuation runs parallel to the line of tubercles at the base of the dactylus; in *stenodactyla* the continuation is directed obliquely towards the line at the base of the dactylus."

Family **Gecarcinidæ** Dana.

6. **Gecarcinus ruricola** (Linnæus).

Cancer ruricola Linnæus, Sys. Nat. Ed. 10, I, p. 626, 1758.

Gecarcinus ruricola Leach. Edin. Encyc., VII, 430, 1814. Ortmann, l. c., p. 740, 1894.

(*a*) 1 ♂. Bahama Islands. (Dry.)

(*b*) 1 ♂. Nicolstown, Andros Island, March 9, '90. (Dry.)

Range: West Indies, Mexico.

Collected at Cuba, Jamaica, Hayti, Martinique.

7. **Cardisoma guanhumi** (Latreille).

Latreille, Ency. Méth., Hist. Nat. Insectes, X, 685, 1825.

Ortmann, l. c., p. 735, 1894.

(*a*) 1 ♂, 1 ♀, ♂ 1, juv. Move sluggishly, make holes in the ground by side of road under trees, Nassau, N. P., Jan. 25, '90.

Range: East and west coasts of Central America, West Africa.

Collected at Cuba, Jamaica, Hayti, St. Thomas, Barbadoes.

Family **Grapsidæ** (Dana).

8. **Leiolophus planissimus** (Herbst).

Cancer planissimus Herbst, l. c., p. 3, pl. LIX, 1804.

Miers, Ann. Mag. Nat. Hist. Ser. 5, I, 1878, p. 153.

(*a*) 3 ♂, 1 ♀. On shore, just south of Ft. Montagu, Nassau, N. P., Jan. 22, '90.

(*b*) 2 ♂ juv. Ocean side of Salt Cay, N. P., Jan. 31, '90.

Range: "Cosmopolitan, except the colder seas," Ortmann.

Collected at Jamaica.

9. **Plagusia depressa** (Fabricius).

Cancer depressus Fabricius, Entom. Sys. Suppl., p. 406, 1775.

Miers, Challenger, Brachyura, p. 272.

(*a*) 2 ♂. Salt Cay, New Providence. (Dry.)

Range: Charleston to Brazil, Mediterranean to St. Helena.

Collected at Cuba, Jamaica.

10. **Sesarma cinerea** (Say).

Sesarma ricordi Milne Edwards, Annal Sci. Nat. (3) Zool. t. 20, p. 183, 1853.

Ortmann, Carcinologische Studien, Zool. Jahrb., Bd. X, 1897.

(*a*) 1 ♀ with ova. Under side of stones, Dix. Pt., near Nassau, N. P., Feb. 4, '90.

Range: West Indies.

Collected at St. Domingo, Hayti, Jamaica, St. Thomas.

11. **Pachygrapsus transversus** (Gibbes).

Gibbes, Proc. Am. Ass. Adv. Sci., III, p. 182, 1850.

Kingsley, l. c., 1880, p. 198.

(*a*) 4 ♂ (juv.), 3 ♀ with ova. Nassau, N. P., under stones Jan., 1890.

Range: Warm and temperate waters of both hemispheres.

Collected at Cuba, Jamaica, Virgin Islands, Barbadoes.

12. **Grapsus grapsus** (Linnæus).

Cancer grapsus Linnaeus, Sys. Nat. ed. X, I, p. 630, 1758.

Smith, Trans. Conn. Ac. IV, 1880, p. 256. Ortmann, l. c., p. 703, 1894.

(*a*) 1 ♂, 2 ♀. Near Nassau, N. P., Jan., '90.

Range: Warm waters of both hemispheres.

Collected at Cuba, Jamaica, Hayti.

13. **Goniopsis cruentatus** (Latreille).

Grapsus cruentatus Latreille, Hist. Nat. des Crust. VI, p. 70, 1803.

Kingsley, l. c., 1880, p. 190. Ortmann, l. c., p. 701, 1894.
(*a*) 1 ♂. (Dry.)
(*b*) 2 ♀. On shore near Nassau, N. P., Jan. 23, '90.
Range: American and African Coasts of the Atlantic ocean.
Collected at Cuba, Jamaica, Hayti.

BRACHYURA—CYCLOMETOPA.

Family **Oziidæ** Ortmann.

14. **Eriphia gonagra** (Fabricius).

Cancer gonagra Fabricius, Sp. Ins., p. 505, 1781.
Ortmann, l. c., p. 480, 1894.
(*a*) 1 ♂. In pools on shore, Nassau, N. P., Jan. 21, '90.
(*b*) 1 ♀. Dix Pt., near Nassau, N. P., Feb. 4, '90.
(*c*) 1 ♂. Salt Cay. Ocean side, near N. P., Jan. 31, '90.
Range: Atlantic coast from Carolina to Rio Janeiro.
Collected at Bahamas, Cuba, Jamaica, Hayti, Barbadoes.

15. **Domœcia hispida** Eydoux et Souleyet.

Eydoux et Souleyet, Voy. Bonite, I, Crust., p. 235, 1842.
Ortmann, l. c., p. 478, 1894.
(*a*) 1 ♀, juv.
Range: West Indies, Florida, Cape Verde Islands, Senegal, Pacific Islands.
Collected at Cuba, Jamaica, St. Thomas, Guadaloupe.

16. **Panopeus herbstii** Milne-Edwards.

Milne-Edwards, Hist. Nat. Cr., I, p. 403, 1834.
Benedict & Rathbun, Proc. U. S. Nat. Mus., XIV, p. 358, 1891.
(*a*) 1 ♂. Nassau, N. P., Jan., 1890.
Range: Rhode Island to Brazil.
Collected at Bahamas, Jamaica, St. Thomas, Curaçao, Trinidad.

17. **Panopeus occidentalis** Saussure.

Saussure, Rev. and Mag. de Zoöl. (2), IX, p. 502, 1857.
(*a*) 1 ♀. Near Nassau, N. P., Febr., '90.
(*b*) 1 ♂. On shore near Nassau, N. P., Jan. 22, '90.
Range: Atlantic from S. C. to Brazil.
Collected at Jamaica, Old Providence, Guadaloupe, Curaçao, Trinidad.

18. **Panopeus americanus** Saussure.

Saussure, Rev. et Mag. de Zoöl. (2), IX, p. 502, 1857.
(*a*) 1 ♂, 4 ♀. Near N. P., Bahamas, Jan.–Febr., 1890.
(*b*) 1 ♂. On shore, near Nassau, N. P., Jan. 22, '90.
(*c*) 1 ♂. Nassau, N. P., Febr. 24, 1890, Dix Pt.
Range: West Indies to Brazil.
Collected at Jamaica, St. Thomas.

Family **Xanthidæ** Ortmann.

19. **Chlorodius floridianus** Gibbs.

Gibbs, l. c., p. 175, 1850.
(*a*) 1 ♀. Collected in pools and under stones, N. P., and neighboring cays.
(*b*) 1 ♂. Dix Pt., Nassau, N. P., Febr. 24, 1890.
(*c*) 1 ♂, 2 ♀. Near New Providence, Jan.–Feb., 1890.
(*a*) 1 ♂, 3 ♀. On shore near Nassau, N. P., Jan. 22, '90.
Range: Florida to Brazil.
Collected at Jamaica, St. Thomas, Barbadoes.

20. **Lophactæa lobata** (Milne-Edwards).

Cancer lobatus Milne-Edwards, Hist. Nat. Crustacés, I, p. 375, 1834.
Lophactæa lobata A. Milne-Edwards, Nouv. Arch. Mus. Hist. Nat., I, p. 249, Pl. XVI, 1865.
(*a*) 1 ♀. Quarantine station, Jan. 25, '90.
Range: West Indies, Gulf of Mexico, Bermuda.
Collected at Jamaica and the Antilles.

21. **Heteractæa ceratopa** (Stimpson).

Pilumnus ceratopus Stimpson, Ann. Lyc. Nat. Hist. N. Y., VII, p. 215, 1862.

Heteractæa ceratopus Kingsley, l. c., 1879, p. 396.

(*a*) 1 ♀. Dix Pt., Nassau, N. P., Febr. 24, 1890.

(*b*) 1 ♀. Quarantine station, N. P., Jan. 25, '90.

Range: Florida and West Indies.

Collected at Guadaloupe.

22. **Actæa acantha** (Milne-Edwards).

Cancer acanthus Milne-Edwards, Hist. Nat. Cr., I, p. 390, 1834.

Actæa acantha A. Milne-Edwards, l. c., p. 278, Pl. XVI, 1865.

(*a*) 1 ♂. Quarantine station near Nassau, N. P., Febr. 10, 1890.

Range: Florida Keys, West Indies.

Collected at Jamaica, Guadaloupe.

PORTUNINEA.

Family **Portunidæ** Ortmann.

23. **Callinectes larvatus** Ordway.

Ordway, Boston Jour. Nat. Hist., VII, p. 573, 1863.

Rathbun. The genus Callinectes, Proc. U. S. Nat. Mus., XVIII, p. 358, 1896.

(*a*) 1 ♂, 1 ♀, spur. juv. On shore, just south of Ft. Montagu, Nassau, N. P., Jan. 22, '90.

Range: Florida to Brazil, West Indies, Cape Verde Islands, Africa.

Collected at Bahamas, San Domingo, Jamaica, St. Thomas.

24. **Callinectes tumidus** Ordway.

Ordway, l. c., p. 574, 1863.

Rathbun, l. c., p. 359, 1896.

(*a*) 1 ♂. Nassau, N. P., Jan. 21, 1890, common in shoal water.

Range: Florida to Brazil, West Indies.

Collected at Jamaica, Hayti, Old Providence.

25. **Acheloüs depressifrons** Stimpson.

Amphitrite depressifrons Stimpson, Ann. Lyc. Nat. Hist. N. Y., VII, p. 58, 1862.

Acheloüs depressifrons Stimpson, ibid., p. 223.

(*a*) 1 ♀. Quarantine station, N. P., Jan. 25, '90.

Range: South Carolina to Florida, Bermuda, West Indies. Besides this specimen from New Providence, the Princeton Museum possesses one from the Virgin Islands; the only two localities reported from the West Indies.

26. **Acheloüs ordwayi** Stimpson.

Stimpson, Notes on N. Am. Crustacea, Ann. Lyc. Nat. Hist., N. Y., p. 224, 1862.

Smith, Trans. Conn. Acad., II, p. 9.

(*a*) 1 ♂. Quarantine station, N. P., Jan. 25, '90.

(*b*) 1 ♀, with ova. Dredged near Nassau, N. P., Jan. 22, '90.

Range: Florida and West Indies.

Collected at St. Thomas.

27. **Acheloüs tumidulus** Stimpson.

Stimpson, Bull. Mus. Comp. Zoöl., II, p. 149, 1870.

(*a*) 1 ♂. Dredged near Nassau, N. P., Jan. 22, '90.

Stimpson describes two specimens from the coast of Florida. The species is probably only the young of *A. ordwayi*, as it only differs from the latter (as noted by Stimpson) in the less prominent frontal spines.

MAIOIDEA..

Family **Periceridæ** Miers.

28. **Macrocœloma eutheca** (Stimpson).

Pericera eutheca Stimpson, Bull. Mus. Comp. Zoöl. II, p. 112, 1870.

Rathbun in Proc. U. S. Nat. Mus., Vol. XV, No. 901, p. 251, 1892.

(*a*) 1 ♀. Dredged near Nassau, N. P., Jan. 22, '90.

Range: Florida, West Indies.

Collected at Cuba.

29. **Microphys bicornutus** (Latreille).

Pisa bicornuta Latreille, Encyc. Méth., Hist. Nat. Insectes, X, p. 141, 1825.

Microphys bicornutus, A. Milne-Edwards, Nouv. Arch. Mus. Hist. Nat., VIII, p. 247, 1872.

Rathbun, l. c. (No. 901), p. 253.

(*a*) 2 ♂, 5 ♀. Common under rocks between tides and in pools, N. P., Jan., '90.

(*b*) 1 ♂. Quarantine station, N. P., Jan. 25, '90.

(*c*) 1 ♀. Nassau, N. P., Jan., '90.

(*d*) 1 ♂. On shore near Nassau, just south of Ft. Montagu, Jan. 22, '90.

(*e*) 1 ♀ juv. "Sea gardens," near Nassau, N. P., Febr., '90.

(*f*) 1 ♂, juv. Ocean side of Salt Cay, Febr. 6, '90.

(*g*) 1 ♂, juv. Nassau, N. P., Febr. 15, '90.

(*h*) 1 ♀ juv. Salt Cay, N. P., ocean side, Jan. 31, '90.

Range: Florida, West Indies to Brazil, Bermuda.

Collected at numerous islands of the West Indies.

30. **Othonia aculeata** (Gibbes).

Hyas aculeata Gibbes, l. c., p. 171, 1850.

Rathbun, l. c., p. 255, 1892.

(*a*) 1 ♂. On shore just south of Ft. Montagu, Nassau, N. P., Jan. 22, '90.

Range: Florida and West Indies.

Collected at Cuba, Bahamas, Jamaica, St. Thomas, Guadaloupe.

31. **Othonia lherminieri** Schramm.

Schramm, Crust. de la Guadaloupe, 20, 1867.

(*a*) 1 ♂, 2 ♀. On shore near Nassau, Jan. 22, '90.

The three specimens in the collection are broken and imperfect. I place them doubtfully in this species.

Range: Atlantic coast; S. C. to Brazil.

32. **Mithrax pilosus** Rathbun.

Rathbun, l. c., p. 262, Pl. XXXIX (No. 901), 1892.

(*a*) 1 ♂. Near New Providence, Jan., '90.

(*b*) 2 ♂ (fragmentary). Salt Cay, ocean side, New Providence, Jan. 31, '90.

Miss Rathbun's four specimens were collected in Abaco, Bahamas.

33. **Mithrax cinctimanus** (Stimpson).

Mithraculus cinctimanus Stimpson, Ann. Lyc. Nat Hist. N. Y., VII, p. 186, 1862.

Rathbun, l. c., p. 268 (No. 901), 1892.

(*a*) 1 ♀. Dix Pt., Nassau, N. P., Febr. 24, '90.

(*b*) 1 ♂. Quarantine station, N. P., Jan. 25, '90.

(*c*) 1 ♀ (broken). Near Nassau, N. P., Febr., 1890.

(*d*) 1 ♀ (juv.). Nassau, N. P., Jan. '90.

Range: Florida coast, West Indies, Gulf of Mexico.

Collected at Andros island, Jamaica, St. Thomas, Guadaloupe.

34. **Mithrax forceps** (A. Milne-Edwards).

Mithraculus forceps A. Milne-Edwards. Miss. Sci. au Mexique, pt. 5, I, p. 109, 1875.

Rathbun, l. c., p. 267 (No. 901), 1892.

(*a*) 6 ♀, mostly young. Ocean side of Salt Cay, Febr. 6, '90.

(*b*) 1 ♂ fragmentary. Nassau, N. P.

(*c*) 3 ♀. "Sea gardens," near Nassau, N. P., Febr., '90.

(*d*) 1 ♂, 2 ♀ juv.

Range: From North Carolina to Brazil and Guiana.

Collected at Nassau, Bahamas, Old Providence, St. Thomas, Curaçao.

35. **Mithrax sculptus** (Lamarck).

Maia sculpta Lamarck, Hist. Anim. sans Vert., V, p. 242, 1818.

Rathbun, l. c. (No. 901), p. 271, 1892.

(*a*) 1 ♂, 1 ♀. Quarantine station, N. P., Jan. 25, '90.

Range: Florida, West Indies to Venezuela, Surinam.

Collected at numerous localities in the West Indies.

36. **Mithrax coronatus** (Herbst).

Cancer coronatus Herbst, Natur. der Krabben u. Krebse., I, p. 184, Pl. XI, fig. 63, 1785.

Rathbun, l. c. (No. 901), p. 272, 1892.

(*a*) 1 ♂. Salt Cay, ocean side, near New Providence, Jan. 3, '90.

(*b*) 1 ♂ juv. Ocean side of Salt Cay, Febr. 6, '90.

Range: Florida, West Indies, Central America, Brazil.

Collected at Abaco, Bahamas, Jamaica, Cuba, St. Thomas, Guadaloupe.

Family **Inachidæ** Miers.

37. **Acanthonyx petiverii** Milne-Edwards.

Milne-Edwards, Hist. Nat. Crust., I, p. 343, 1834.

(*a*) 1 ♀ broken. Under rocks, between tides and in pools. Nassau, N. P., Jan., '90.

Range: West Indies to Brazil and California to Chili; Galapagos.

Collected at Cuba, Jamaica, St. Thomas, Guadaloupe, Martinique.

DROMIIDEA.

Family **Dromiidæ** Dana.

38. **Dromidia antillensis** Stimpson.

Stimpson, Notes on N. Am. Crust., Ann. Lyc. Nat. Hist. N. Y., VII, p. 71, 1859.

(*a*) 1 ♀. Nassau, N. P., Febr. 15, '90.

Range: Florida, West Indies, Brazil.

Collected at Antilles, Jamaica, St. Thomas.

HIPPIDEA.

Family **Hippidæ** Stimpson.

39. **Remipes cubensis** Saussure.

Saussure, Rev. Mag. Zoöl. (2), IX, p. 503, 1857.

Ortmann, Die geog. Verbreit. der Decap. gruppe der Hippidea, Zoöl. Jahrb., IX, p. 219, 1896.

Remipes scutellatus (Fabricius), Henderson, Chall. Anomura, p. 38, 1888.

(*a*) 19♀ (with ova). Beach at Nicolstown, Andros Island, Apr. 4, '90.

(*b*) 2♂, 9♀. Quarantine station near New Providence, Jan. 25, '90.

(*c*) 1♀. Nassau, N. P., Jan., 1890.

Range: "American and African shores of Atlantic," Ortmann (l. c. supra).

Collected at Cuba, Jamaica, St. Christophers, Barbadoes.

GALATHEIDEA.

Family **Porcellanidae** Henderson.

40. **Porcellana sayana** Leach.

Pisidia sayana Leach. Dict. d. Sci. Nat., XVIII, p. 54, 1820.

Porcellana ocellata Gibbes, l. c., p. 190, 1850.

Henderson, Challenger, Anomura, p. 109, 1888.

(*a*) 1♂. Came out of a shell inhabited by a large hermit crab. Nassau, N. P., Jan. 26, '90.

Range: West Indies and Southern shores of U. S.

Collected at Antilles, Jamaica, St. Thomas.

41. **Pachycheles panamensis** Faxon.

Faxon, Mem. Mus. Comp. Zoöl., XVIII, p. 75, Tab. 15, 1895.

Ortmann, Zoöl. Jahrb., X, 1897, p. 293.

(*a*) 1♂, 2♀. Ocean side of Salt Cay, Febr. 6, '90.

Size of ♂ 5½ mm. long, 5 mm. broad; of ♀ 5 mm. long, 6 mm. broad. These specimens have been kindly examined for me by Dr. Ortmann, who finds them identical with Faxon's type from Panama, and also very close to the Cape Verde *P. barbatus* A. Milne-Edwards. This is the first recorded specimen of *P. panamensis* from the West Indies.

42. **Petrolisthes armatus** (Gibbes).

Porcellana armata Gibbes, l. c., p. 190, 1850.

Petrolisthes armatus Stimpson, Ann. Lyc. Nat. Hist., N. Y., VII, p. 73, 1862.

Ortmann, Zoöl. Jahrb., X, 1897, p. 280.

(*a*) 1 ♂, 1 ♀. Ocean side of Salt Cay, Feb. 6, '90.

Ortmann (l. c. supra), gives full synonymy of this species and makes its distribution circumtropical; West Indies to Brazil, Gibraltar, California to Panama, Indo-Pacific.

Collected at Cuba, Jamaica, St. Thomas, Barbadoes.

43. **Petrolisthes tridentatus** Stimpson.

Stimpson, Ann. Lyc. Nat. Hist., N. Y., VII, p. 75, Pl. I, 1859.

(*a*) 1 ♂. Along shore, near Nassau, N. P, Feb. 20, '90.
(*b*) 2 ♂, 5 ♀. Salt Cay, N. P., ocean side, Jan. 31, '90.
(*c*) 2 ♂, 1 ♀. Under sponges, Nassau, N. P., Jan. '90.

Range: West Indies.

Collected at St. Thomas, Barbadoes.

PAGURIDEA.

Family **Cœnobitidæ** Dana.

44. **Cœnobita diogenes** (Latreille).

Milne-Edwards, Hist. Nat. Crust., II, p. 240, Pl. 22, 1837.

(*a*) 2 ♂. Nicolstown, Andros Island, March 23, '90.
(*b*) 2 ♂, 1 ♀. Nassau, N. P., Jan. 16, '90.
(*c*) 2 ♀. On beach, Quarantine station, near Nassau, N. P., 1890.

(*d*) 1 ♀, juv. In pools and under stones, New Providence and neighboring cays.

Range: Florida to Brazil, West Indies, Bermuda.

Collected at Antilles, Cuba, Jamaica, Hayti, Turks Island, St. Thomas, Barbadoes.

Family **Paguridæ.**

45. **Petrochirus granulatus** (Olivier).

Pagurus granulatus Olivier, Encyc. Méth., VIII, p. 640, 1811.

Henderson, in Challenger, Anomura, p. 58, 1888.

(*a*) 3 ♂.

(*b*) 1 ♂, 1 ♀. In shell of *Strombus gigas*, Nassau, N. P., Jan. 26, '90.

Range: West Indies, Gulf of Mexico to Brazil, Cape of Good Hope.

Collected at Antilles, Cuba, Jamaica.

The common large West Indian hermit crab.

46 (?) **Clibanarius vittatus** (Bosc.).

Pagurus vittatus Bosc. Hist. des Crust., II, p. 8, pl. XII, 1802.

Kingsley, Proc. Acad. Nat. Sci. Phil., p. 236, 1878.

(*a*) 1 ♂ imperfect. In small shell of *Strombus gigas*, beach near Nassau, N. P., Jan. '90.

(*b*) 1 (?) fragmentary. Near Nassau, N. P., Febr. 1, '90.

Range: Fort Macon to Florida, West Indies, Brazil.

I refer these imperfect specimens doubtfully to this species. The chelæ are wanting in (*a*), and (*b*) is too much broken to be of any value in the determination.

47 (?) **Clibanarius tricolor** (Gibbs).

Pagurus tricolor Gibbes, Proc. Amer. Assoc., p. 189, 1850.

(*a*) several specimens.

(*b*) 1 ♂. South side New Providence, in small shells of *Strombus gigas*.

The determination is doubtful, as the specimens are very poor and have almost entirely lost their color. They are all withdrawn into the shells of various littoral mollusks.

Family **Parapaguridæ** Smith.

48. **Parapagurus** sp.

(*a*) 2 ♀. Dredged, Jan. 22, '90, Nassau, N. P.

Length of thorax 3 and 5 mm. respectively.

I refer these imperfect, colorless specimens doubtfully to some species of *Parapagurus*.

LORICATA.

Family **Panuliridæ** Bate.

49. **Panulirus argus** (Latr.).

Palinurus argus Latr. Milne-Edwards, Hist. Nat. Crust., II, p. 300, 1837.

(*a*) 1 ♂, 1 ♀. New Providence, Jan. 27, '90. Holes in sand between tides, about 5–6 in. deep, "very shy."[1]

(*b*) 1 ♀. Nassau, N. P., Jan., 1890. (Dry.)

Range: West Indies to Brazil.

Collected at Antilles, Cuba, Jamaica.

STENOPIDEA.

Family **Stenopidæ** Bate.

50. **Stenopus hispidus** (Latreille). (Pl. xxix, Fig. 1.)

Palæmon hispidus Olivier, Encyclop., VIII, p. 666, 1811.

Stenopus hispidus Latreille, Regne animal de Cuvier, ed 2, IV, p. 93.

Bate, Challenger, Macrura, p. 211, Pl. XXX.

Herrick, The Life History of Stenopus, Nat. Acad. of Sciences, Vol. V, p. 339.

(*a*) 1 ♂. Nassau, N. P., Jan. 22, '90. In life the antennæ are carried in front, not bent back.

I note the characters of special importance in order to compare this already described species of *Stenopus* with the two species following. Rostrum with a median dorsal row of 6 spines bifurcated at extremity, a lateral row of 3 or 4 spines on each side of rostrum; no ventral spines. Back of the sixth dorsal spine a double row. Rostrum does not reach to end of peduncle of inner antennæ. Carapace of thorax very rough, with firm, sharp spines which are longer on the dorsal than on the lateral regions. Abdomen thickly armed with outwardly projecting spines. Third pereiopod long, abundantly armed with spines. The propodos with six rows above and below and two on each lateral surface.

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[1] This label is marked as doubtfully belonging to this specimen.

Measurements: Total length 50.5 mm., length of cephalothorax 16.5 mm., of abdomen 34 mm., of rostrum 6 mm., of telson 9.5 mm.

Unless the Eastern form should prove distinct from the West Indian, we have a widely distributed species occurring in the warm waters of both hemispheres. It has been reported from: Indian ocean (Olivier), Australia (Peron and Lesneur), Borneo and Philippines (Adams and White), South Pacific (Dana), Amboina (DeMan), Fiji Islands and Bermuda (Bate), Cuba (Von Martens), Bahama Islands (Herrick).

I introduce a figure of this specimen (Pl. xxix, Fig. 1), although not a new species, in order to compare it with the two following species, figures of which have not yet appeared.

51. **Stenopus semilævis** Von Martens (Pl. xxix, Fig. 2).

Von Martens, Ueber Cubanische Crustaceen, Arch. f. Naturgesch., Bd. 38, p. 144, 1872.

(*a*) 1 ♂, 1 ♀ with ova. Under large sponge. New Providence, Jan., '90.

My specimens correspond very closely, except in certain minor particulars noted below, with the description given by Von Martens of a species "probably from the West Indies," which he found undescribed in the Berlin Museum and which he called *S. semilævis*.

Von Martens' description (l. c., supra) I reproduce: "Cephalothorax spiny; abdomen smooth; rostrum short, not longer than the peduncle of the inner antennæ, compressed laterally and prolonged as a ridge nearly to the sharply marked cervical furrow, above with four teeth, below teeth wanting. Carpus of third pair of pereiopods quadrangular as in *S. hispidus*, but the chelæ compressed, with smooth sides and not so long; chelæ, including the dactyl, twice as long as broad; the upper margin sharper than the under and smooth, the under serrated. The dactyl half as long as the palma; the back of the dactyl keeled, serrated. Length from tip of rostrum to tip of telson 12 mm. Length of third pereiopod 13 mm. Breadth of chela 3 mm. The fourth pereiopod shorter than third."

I note the following peculiarities in my specimens: *Dorsal surface of rostrum with six teeth;* the fourth and sixth have each a minute subsidiary tooth. *Ventral surface with a single, not very prominent tooth.* Both margins of the chelæ of the third pereiopods very finely serrated, a rather prominent keel on the upper margin. The third pereiopod of the right and left sides similar. Telson spiny. The large specimen (♀) is 15 mm. long, the ♂ slightly smaller. Length of chelæ in ♀, 6 mm., breadth, 2.5 mm.

Not having the opportunity of comparing the Bahama specimens with Von Martens' type I prefer to consider these slight variations as possibly due to imperfect description, and to place my specimens, provisionally, at least, with Von Martens' species.

S. semilævis differs from *S. hispidus* mainly in the teeth of rostrum, the shorter rostrum, the proportionately shorter and thicker hand, the less spiny carapace of cephalo-thorax and the smooth abdomen.

52. **Stenopus scutellatus** n. sp. (Pl. xxix, Fig. 3).

(*a*) 1 (?) ♂. Under coral, near low water, Silver Cay, N. P.

Total length from tip of rostrum to tip of thorax 18 mm. Length of rostrum 3 mm., of cephalo-thorax 7 mm.

Rostrum has a single row of ten spines on median dorsal line; back of the tenth a double row of three spines extend to the cervical furrow. On median ventral line of rostrum are six spines; *no lateral spines* on rostrum. Rostrum longer than in

S. hispidus, extending beyond the peduncle of inner antennæ. Whole surface of carapace covered with delicate spines obscurely arranged in rows; usually curved forward, with a somewhat reflexed tip. Spines on dorsal surface of first two abdominal segments short and straight in a double row pointing forwards; on third segment several rows, stouter, pointing outwards; on the fourth, fifth and sixth segments spines are longer, pointing backwards. In the middle of the posterior portion of the tergum of the third abdominal segment there is a polished, slightly elevated, shield-shaped area, with crenulated margins, about 1 mm. in length. The median tergal region of fourth segment is smooth and polished, surrounded by a row of appressed spines, the same being true to a less extent of the fifth segment. I have taken the specific name from this peculiar scutellar area on the third abdominal segment. This feature seems to correspond to a triangular but less prominent area on the similar segment in *S. hispidus* which is prolonged into a smooth dorsal ridge on the next segment.

Telson lance-shaped, with a double row of spines between which is a longitudinal groove about as long as the uropodal lamellæ, which are finely serrated on their margins, and, as the telson, fringed with stiff hairs.

Eyes on short peduncles which are armed above with three short spines projecting over the cornea, and with a few spines at the anterior margin. Cornea (in alcoholic specimen) bluish-black. Inner antennæ; peduncle with a few weak spines at distal end of segments. Outer antennæ; peduncles with strong, forwardly projecting spines. Scale lined on inner margin with long, closely set hairs and prolonged into a ciliated bristle. Flagella more than twice the length of body. Third maxillipedes when extended reach a little further than extremity of rostrum; the three distal segments about equal in length.

First pair pereiopods wanting in my specimen. Second pair slender, chelate, segments of equal length. Third pair of similar proportions to those in *S. hispidus;* chelæ 7 mm. long; propodos laterally compressed and somewhat triangular in cross section, broad above; on the dorsal margin a double row of eleven spines each, on the ventral margin a single row of nine spines; two or three rows of minute spines on lateral surfaces. A number of long, soft hairs over the fingers, especially at the tips. Hands of the two chelapods similar in size. Carpus and ischium together about equal to propodos, each armed with rows of spines. Fourth pair long and slender; dactylus bifid; propodos slightly spiny, one-half length of carpus. Carpus and propodos obscurely articulated. Fifth pair pereiopods undeveloped. Pleopods biramous, except first, with two or three spines each on the protopodite.

From the single specimen at my disposal I would compare this species with *S. hispidus* as follows: Rostrum proportionately longer (nearly ½ length of cephalothorax, in *n. sp.* (⅓ in *hispidus*), longer than peduncle of inner antennæ. Six ventral teeth (*hispidus* none), no lateral teeth, single dorsal row of ten teeth (*hispidus* six). Flagella of outer antennæ fully twice the length of body; proportion 2:1 for *n. sp.*, 7:5 for *hispidus*. Tergum of third abdominal segment with shield-shaped area. Third maxillipedes proportionately shorter than in *hispidus*. Spines on cephalothorax equally long, but less rigid than in *hispidus*, giving in general a less thorny character to the new species.

EUCIPHIDEA.

Family **Palæmonidæ** Bate.

53. **Palæmon savignyi** (Bate).

Brachycarpus savignyi Bate, Challenger, Macrura, p. 795, Pl. 129, 1888.

Ortmann, Zoöl. Jahrb., Bd. V, p. 727.

(*a*) 1 specimen. Near Nassau, N. P., Febr., '90.

(*b*) 1 specimen. Nassau, N. P., 1890.

(*c*) 5 ♀ with ova. Nassau, N. P., 1890.

Bate's specimen was from Bermuda, "in shallow water."

"This is the most northern limit of genus Palæmon," Ortmann.

The species has not been described from any other localities.

54. **Leander northropi** n. sp. (Pl. xxx, Fig. 4).

(*a*) 1 specimen. Nassau, N. P., Jan., 1890.

A single specimen with a total length of 30 mm. Length of cephalothorax to tip of rostrum 11.5 mm.

Cephalothorax with small tooth below orbit and a very minute tooth below this and a little back from the anterior margin *on the lateral surface.*

Length of rostrum to posterior end of orbit 7 mm., slightly curved upwards toward apex. *Ten* teeth above, *four* below; the first dorsal tooth forms with the tip of rostrum a bifid extremity. A long interval between first and second tooth; interval between second and third one-third the length of that between first and second; fourth, fifth and sixth teeth follow at slightly diminishing intervals, the sixth being over the posterior part of orbit of eye. *Seventh, eighth and ninth teeth close together, posterior to orbit of eye.*

The first ventral tooth is a little in front of second dorsal, second ventral below second dorsal; third and fourth at equal intervals between second ventral and orbit of eye.

Inner antennæ: Peduncle reaches beyond second ventral tooth of rostrum; proximal segment about equal to the two distal. Upper flagellum bifid; united proximal portion of 14 segments; the shorter branch has 12 segments; united therefore for *more than half its length.* The longer branch reaches beyond the undivided flagellum.

Outer antennæ: Scaphocerite with lamellar portion slightly longer than spinose, reaches beyond first ventral tooth of rostrum; flagellum exceeds the length of the body.

Third pair maxillipedes reach to end of peduncle of inner antennæ.

First and second pereiopods: Long, slender and chelate; second longer than first; chela in second as long as carpus. Third and fourth pereiopods terminate in claws.

Pleopods, biramous, setose. Telson, lanceolate, 4 mm. long, noticeably shorter than uropods, distal extremity with two sharp spines. Outer uropod imperfectly divided transversely, the proximal division ending in a lateral spine.

This species is allied to *L. petitinga* F. Müller, from Brazil (see Ortmann, Revista do Museu Paulista, II, p. 191, 1897) and to *L. maculatus* Thallwitz (Abh. Mus. Dresd., III, p. 19, 1891) from West Africa.

I am indebted to Dr. Ortmann for the preparation of the following table, which exhibits the relationship:

	L. maculatus.	**L. northropi.**	**L. petitinga.**
Inner antennæ	12–13 segments united 8 segments free.	14 segments united 12 segments free.	9 segments united 20 segments free.
Teeth of rostrum	$\frac{6+1}{3}$ 1 posterior to orbit.	$\frac{9+1}{4}$ 4 posterior to orbit.	$\frac{6+1}{5-6}$ 1 posterior to orbit.

Family **Hippolytidæ** Ortmann.

55. **Tozeuma carolinense** Kingsley.

Kingsley: Proc. Acad. Nat. Sci. Phila., p. 90, 1878.

(*a*) 1 ♀. with ova. Dredged in about 16 ft. Near Quarantine station, Jan. '90.

Kingsley's specimens are from Fort Macon and Beaufort, N. C., and Charlotte Harbor, Fla.

Measurements of Bahama specimen: total length 41 mm., rostrum 12 mm., cephalothorax (without rostrum) 7 mm., abdomen 22 mm.

Family **Alpheidæ** Bate.

56. **Alpheus edwardsii** (Audouin).

Athanas edwardsii Audouin; Planches de la descrip. de l'Egypte par M. Savigny, Crust., Pl. X, fig. 10, 1810.

Bate, Challenger, Macrura, p. 542, 1888.

(*a*) 4 specimens. Near Nassau, N. P., along shore, Febr. 20, '90.

(*b*) 1 specimen. Nassau, N. P., Jan., '90.

(*c*) 3 specimens. Under coral and in pools between tides, New Providence.

(*d*) 1 specimen. Under coral and in pools between tides, Nassau, N. P., Jan., '90.

(*e*) 2 broken. Near Nassau, N. P., Febr., '90.

The distribution of this species is circumtropical.

57. **Alpheus hippothoë,** De Man.
var. **bahamensis,** n. var. (Pl. xxx, Fig. 5).

(*a*) 24 specimens. Under coral and in pools between tides, New Providence.

(*b*) 3 specimens, one with ova. Nassau, N. P., Jan., '90.

(*c*) 2 specimens, one with ova.

This species is most closely allied to the variety *edamensis* of *Alpheus hippothoë* De Man, from the Bay of Bengal and Indian Archipelago (Arch. de Naturg., Bd. 53, p. 518, 1887). I am indebted to Dr. Ortmann for a communication from Prof. De Man comparing specimens from my material with his own *hippothoë*. As there are certain differences between the West and East Indian specimens I propose to make a new variety for the West Indian.

Total length from rostrum to telson, largest 24 mm., smallest 15 mm. Rostrum reaches nearly to end of first segment of inner antenna, sharp, laterally compressed, prolonged backwards as a distinct keel. Between keel and the prominent eyes a rounded depression. No ocular spines.

Inner antennæ: First joint of peduncle with small spine on outer surface; second joint nearly twice the length of proximal; terminal joint one-half the length of second. Shorter flagellum about the length of peduncle. Longer flagellum slender, about thrice the length of shorter.

Outer antennæ: Peduncle a little longer than that of inner, small spine on basal joint. Flagellum one third longer than long ramus of inner antenna, spinose portion of scaphocerite a little longer than the peduncle. Flabellar portion (scale) a trifle shorter; not quite so long as the peduncle.

Third pair of maxillipedes do not reach beyond end of peduncle of the outer antennæ.

First pair pereiopods: Large chela of largest specimen has a length of 18 mm., of smallest specimen 8 mm. The large chela has a somewhat quadrangular depression on the outer surface, the distal end of which is continued upwards into a well-marked depression on the dorsal margin and extends backward as a groove along the inside of the dorsal surface. A distinct, but less marked depression on the ventral margin. Inner surface of the hand slightly hairy, outer surface nearly smooth. Fingers contorted, color in alcoholic material pale blue. Movable finger slightly longer than thumb. In the small chelapod, which may be on the right or left side, the finger is one-third the length of palm. Carpus of chelapods short. Meros triangular in section; ends distally in a sharp spine on the outer and inner angle. Distal end of meros reaches to end of peduncle of outer antennæ.

Second pair of pereiopods very long. Distal end of meros reaches beyond antennal peduncle. First and second joints of carpus sub-equal, each a little longer than third and fourth together. Third and fourth sub-equal. Fifth about two-thirds length of first; equal in length to fourth and fifth together. Finger about one-half length of thumb. (Fifth joint a little too short in figure.)

Third and fourth pereiopods short and stout, not quite reaching to distal end of meros of second. Length of meros less than three times its breadth. Carpus one half length of meros. *Both carpus and meros with spines on lower margin of distal end.* Propodos serrated on posterior surface.

Fifth pair of pereiopods shorter and more slender. Telson with median furrow. Two small spines on either side of furrow. Outer plate of uropod minutely serrated on end. A sharp spine on its outer distal angle.

Principal variations from *A. hippothoë*—

In new variety: Peduncle of outer antennæ longer than that of inner. Lamellar portion does not reach end of peduncle. Third maxillipedes do not reach beyond antennal peduncle. Relative lengths of carpal joints of seeond pereiopods differ.

Variations from *var. edamensis*—

Finger of small hand shorter than palm (longer in *eda-*

mensis). A quadrangular rather than a triangular depression on side of large hand.

First joint of carpus of second pereiopod is equal in length to second (shorter in *edamensis*). Third and fourth pereiopods less broad than in *edamensis*.

58. **Alpheus websteri** Kingsley.

Kingsley, Proc. Acad. Nat. Sci. Phil., p. 416, 1879.

(*a*) 3 specimens, one with ova. Along shore, near Nassau, N. P., Febr. 20, '90.

(*b*) 2 specimens, one with ova. Nassau, N. P., Jan. 10, '90.

(*c*) 3 specimens, fragmentary. Nassau, N. P., Jan. 10, '90.

Kingsley's type specimens were from Key West; it has been reported by Herrick from Nassau, N. P.

A. websteri is very probably the same as *A. formosus* Gibbs (Proc. Amer. Ass. Ad. Sci., p. 196, 1850). The descriptions apparently tally, though Gibbs makes no mention of the small black spine on the uropod which is mentioned as a characteristic feature by Kingsley and which is very evident in my specimens.

59. **Alpheus nigro-spinatus** n. sp. (Pl. xxx, Fig. 6).

(*a*) Two specimens. Under coral and in pools between tides, New Providence.

Carapace compressed. Rostrum short, acuminate, no longer than spines of ocular hoods; extended backwards as a ridge between the eyes, from each of which it is separated by a rounded depression. Spines of ocular hoods short, acuminate. The front of carapace is thus marked by three, nearly equal, small spines. Inner antennæ: Basal segment of peduncle with small spine (stylocerite); second and third segments, no spines but scattered hairs; second segment a little more than twice as long as the terminal; outer flagellum stouter and shorter than the inner. Outer antennæ: Outer angle of the basal joint of peduncle with a sharp, short spine; scaphocerite broad at base, outer margin produced into a strong spine which is longer than the inner, lamellar portion; distal end of terminal segment of peduncle reaches to tip of scaphocerite. Third pair of maxillipedes reach about to the end of shorter flagellum of inner antennæ; strongly tufted with hair.

First pair of pereiopods: Larger hand much inflated, a slight, but distinct constriction on the upper margin near the articulation of the dactylus, and a deep constriction on the lower margin. Thumb contorted; a groove on the outer margin, the inner surface thickly covered with hairs and punctate. Dactylus contorted; extends slightly beyond thumb; inner surface with tufts of hair. Small hand (which on the one specimen is left, the other right) has a longer and more slender dactylus and thumb. Length of large hand 16 mm.; breadth 6.5 mm. Length of small hand 9 mm.; breadth 4 mm.

Second pair of pereiopods: Carpus five-jointed, proximal segment the longest, slightly longer than the second and third together; second and fifth segments each a little longer than one-half the length of first; third and fourth the shortest, subequal. Posterior pereiopods; meros without spines. Telson broadly triangular; extremity truncate; two small spines on either side of median line of dorsal surface; the outer ramus of uropod bears on its external distal angle a large, very black spine, which is distinguished from the similar black spine of *A. websteri* Kingsley (l. c., p. 416, 1879) by its much larger size and consequently more prominent appearance. Length of specimens 25 mm. and 22 mm. respectively.

60. **Alpheus minor** Say.

Say, Jour. Acad. Nat. Sci. Phil., I, p. 245, 1818.

Kingsley, Bull. U. S. Geol. Survey, IV, p. 190, 1878.

Bate, Challenger, Macrura, p. 558, Pl. C, 1888.

(*a*) numerous specimens, from brown sponges.

(*b*) 1 ♀ with ova. Along shore near Nassau, N. P., Febr. 20, '90.

(*c*) 10 specimens, from brown sponges.

Range: From Cape Hatteras (U. S. F. C. 1885) to St. Paul's Rock (Bate, Challenger). Both shores of Central America.

Collected at Jamaica, New Providence.

Lot (*c*) may possibly be a variety as the thumb is shorter than the typical *minor*, but otherwise there seems to be no difference.

61. **Alpheus saulcyi** Guérin.

Guérin, in Hist. du Cuba, 1857.
Herrick, Memoires Nat. Acad. Sci., Vol. V, p. 381.
(*a*) 5 specimens, from green sponges. Febr. '90.
(*b*) 1 specimen, near Nassau, Febr. 5, '90.
(*c*) 1 specimen, ♂, from green sponge.
(*d*) 1 specimen, from sponge, Mar. 1, '90.
(*e*) 1 specimen, from sponge, Mar. 1, '90.
(*f*) 2 specimens, Nassau, N. P., Jan., '90.
Range: West Indies.
Found at Nassau, Martinique.

62. **Athanas ortmanni** n. sp. (Pl. xxx, Fig. 7).

(*a*) 1 specimen. Along shore, near Nassau, N. P., Febr. 20, '90.

Rostrum slender and pointed, reaching a little beyond the second joint of peduncle of inner antennæ. Antero-lateral margin of carapace extends obliquely backward, prolonged in front of eye into minute spine. Eye-stalk short, not projecting beyond carapace. The eye is seen through the somewhat transparent carapace as in *Alpheus*. Inner antennæ, with stylocerite reaching to distal end of second segment of peduncle. From the peduncle arise two flagella of nearly equal length, the upper somewhat more slender than the lower, bearing on the fourth segment from base a minute, subsidiary flagellum.

Outer antennæ with scaphocerite nearly as long as the peduncles of inner antennæ, broad and fringed with hairs. Third pair of maxillipedes reach slightly beyond the distal end of scaphocerite.

First pair of pereiopods: That on the right side is robust with swollen chela, terminating in slender hooked fingers which are minutely serrated on the opposing edges. Margin of chela entire, length 5 mm., breadth 2.5 mm. Carpus short. Distal end of meros reaches to extremity of third pair maxillipedes. Left chelapod lacking.

Second pair of pereiopods slender, with very small chelæ. Carpus five-jointed; proximal segment equal in length to the four distal segments. Remaining three pairs of perieopods similar to each other and equal in length to the second pair. Pleopods narrow and biramous. Telson narrow and compressed, with smooth margins. Uropods slightly longer than telson.

Total length of specimen 16 mm.

The species above described agrees generically with *Athanas* Leach (Edin. Ency., VIII, p. 432), with the exception that the eyes are entirely covered by the carapace. I propose, rather than found a new genus on the single specimen, to amend Leach's definition of *Athanas* by changing the statement, "Opthalmopoda short, scarcely reaching beyond frontal margin of carapace" (Bate, Challenger, Macrura, p. 528), to *ophthalmopoda short, covered by, or scarcely reaching beyond the frontal margin of carapace.*

There are four hitherto described species of *Athanas:*

A. nitiscens Leach. England and Norway, Mediterranean to Cape Verde Islands.

A. veloculus Bate (l. c., p. 529). Cape Verde Islands.

A. mascarenicus Richters (Beitrage zur Meeresfauna von Mauritius u. d. Seychellen, p. 164, 1880), Mauritius.

A. dimorphus Ortmann, Crust. in Semon's Forschungsreise (Jena. Denks., VIII, 1894, p. 12). East Africa: Dar-es-Salaam.

From all these species *A. ortmanni* may be distinguished at a glance by the form of the large chela.

PENÆIDEA.

Family **Penæidæ** Bate.

63. **Penæus constrictus** Stimpson.

Stimpson, Ann. Lyc. Nat. Hist. N. Y., p. 135, 1871.

Miers, Notes on the Penæidæ, Proc. Zoöl. Soc., London, p. 308, 1878.

(*a*) 1 ♂. Near Nassau, N. P., Febr. 1, 1890.
(*b*) 1 ♀. Nassau, N. P., Febr. 5, '90.
Range: East Coast U. S.
Not before reported from West Indies.
Collected by Stimpson at Beaufort, and Charleston, S. C.

STOMATOPODA.

Family **Squillidæ** Latreille.

64. **Pseudosquilla ciliata** Miers.

Miers, Ann. and Mag. Nat. Hist. (5), V, p. 108, Pl. III, 1880.
Brooks, Challenger, Stomatopoda, p. 53, 1886.
(*a*) 1 ♂ broken. Near Nassau, N. P., Febr., 1890.
Range: Widely distributed over Atlantic and Pacific.
Collected at Cuba, Bahamas, St. Thomas.

65. **Gonodactylus oerstedii** Hansen.

Hansen, Isopoden, Cumaceen und Stomatopoden der Plankton expedition, 1895.

(*a*) 1 ♀. Nassau, N. P., Febr. 5, '90.

(*b*) 1 ♀, fragmentary. Quarantine station, near New Providence, Jan. 25, '90.

(*c*) 1 ♀. Along shore near Nassau, N. P., Febr. 20, '90.

(*d*) 1 ♀. Nassau, N. P., Jan., '90.

(*e*) 1 ♂, 1 ♀, 1 fragmentary. Under coral and in pools between tides, near Nassau, N. P.

(*f*) 1 ♂. (label erased).

(*g*) 2 juv. Dredged in about 16 ft. near Quarantine station, Jan., '90.

Hansen, l. c. supra, p. 65 (and footnote), calls the West Indian *Gonodactylus: G. oerstedii* n. sp. and retains the name *G. chiragra* Fabr. for the East Indian form.

He says (footnote): "This species (*oerstedii*) may be distinguished from the East Indian form, *G. chiragra* Fabr., especially by the character, that it possesses a small keel inside of and close to, the keel that ends in the sublateral process of the posterior margin, while such a secondary keel is wanting in the Indo-Australian species."

Collected at Bahamas, Cuba, Jamaica, St. Thomas.

CIRRIPEDEA.

Family **Lepadidæ** Darwin.

66. **Lithotrya dorsalis** Sowerby.

Sowerby, Genera of Shells, Apr., 1822.

Darwin, A Monograph of the Cirripedia, p. 351, Pl. VIII, 1851.

(*a*) 10 specimens. Salt Cay, N. P., in rocks in surf, Jan. 28, '90.

(*b*) 8 specimen. Salt Cay, Nassau, N. P., ocean side, Febr. 6, 1890.

Range: West Indies, Venezuela, Honduras.

Collected at Barbadoes.

Family **Balanidæ** Darwin.

67. **Acasta cyathus** Darwin.

Darwin, A Monograph of the Cirripedia-Balanidæ, p. 312, Pl. ix, 1854.

(*a*) 4 specimens, in sponge, dredged Jan. 22, '90.

(*b*) 2 specimens, near Nassau, N. P., Febr., '90.

Range: Madeira, West Indies (Darwin).

ISOPODA.

Two species of Isopoda, one probably a *Lygia* of which there are several specimens. Another parasitic on a fish, probably one of the *Cirolanidæ*.

AMPHIPODA.

Several small amphipods undetermined.

PRINCETON UNIVERSITY,
April, 1898.

PLATE XXIX

PLATE XXIX.

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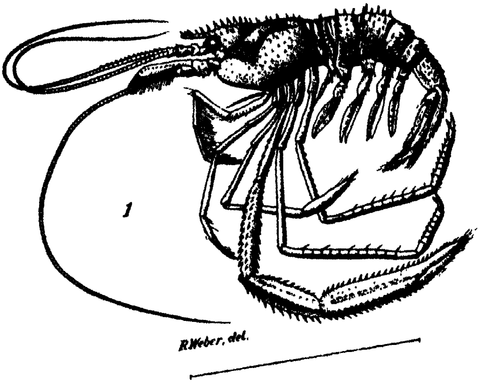
Fig. 2. **Stenopus semilævis,** VON MARTENS 241
Fig. 3. **Stenopus scutellatus** n. sp., RANKIN 242



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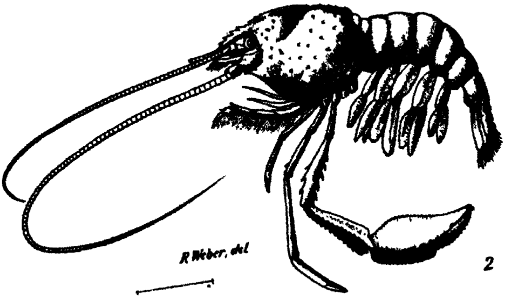

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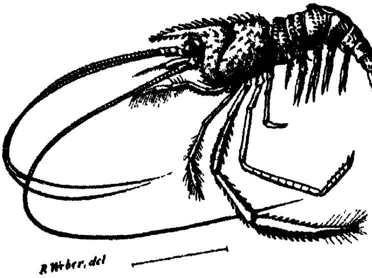

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PLATE XXX.

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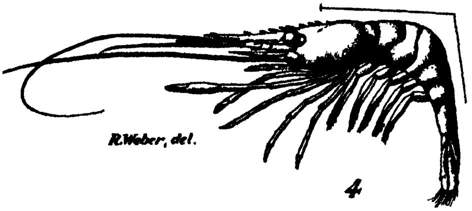
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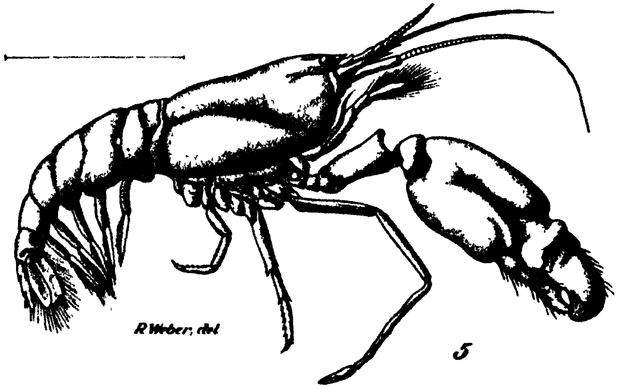
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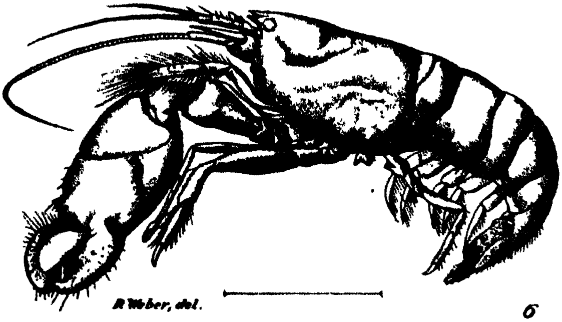
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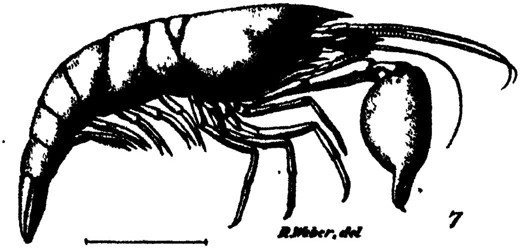
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ANNALS N. Y. ACAD. SCI., XI, No. 13, pp. 259 to 292, August 13, 1898.]

ON A COLLECTION OF CRUSTACEA FROM PUGET SOUND.

W. T. CALMAN, B.SC.

[PLATES XXXI–XXXIV.]

THIS paper presents the results of an examination of the collection of Crustacea made in Puget Sound by the naturalists of the Columbia University Expedition in the summer of 1896, under the leadership of Professor Bashford Dean. I have also included a few additional species from a collection made in the same region by Professor D'Arcy W. Thompson, under whose supervision the paper has been prepared. I am indebted to Mr. N. R. Harrington, Fellow in Zoölogy in Columbia University, for many valuable notes on the specimens collected, the group Crustacea having been in his charge; and I have to thank the Rev. T. R. R. Stebbing for much kind assistance in connection with the AMPHIPODA.

Of the three new species described, the amphipod *Polycheria Osborni* is particularly interesting from the point of view of geographical distribution, since the only other member of the genus comes from the Southern hemisphere. The identification of the Japanese *Philyra pisum* adds another link to the many which already connect the fauna of the Western coast of America with that of the Japanese seas, as we may perhaps say that the first named specific connects it with the fauna of the Southern seas.

The following is a list of species collected by the Columbia University expedition.

DECAPODA.

Metacarcinus magister (Dana).
Cancer productus Randall.
Cancer gracilis Dana.

Lophozozymus bellus (Stimpson).
Trichocarcinus oregonensis (Dana).
Telmessus cheiragonus (Tilesius).
Heterograpsus nudus (Dana).
Heterograpsus oregonensis (Dana).
Pinnixa faba (Dana).
Scyra acutifrons Dana.
Hyas lyratus Dana.
Oregonia gracilis Dana.
Epialtus productus Randall.
Pugettia gracilis Dana.
Philyra pisum De Haan.
Eupagurus ochotensis Brandt.
" **middendorffii** Brandt.
" **tenuimanus** (Dana).
" **splendescens** (Owen).
" **granosimanus** Stimpson.
" **kennerlyi** Stimpson (?)
" **newcombei** Benedict (?)
Cryptolithodes typicus Brandt.
Hapalogaster mertensii Brandt.
Petrolisthes cinctipes (Randall).
Pachycheles rudis Stimpson.
Callianassa gigas Dana.
Upogebia pugettensis (Dana).
Sclerocrangon munitus (Dana).
Crangon franciscorum Stimpson.
Crangon affinis De Haan.
Nectocrangon alaskensis Kingsley
Paracrangon echinatus Dana.
Pandalus Danæ Stimpson.
Hippolyte prionota Stimpson.
" **gracilis** Stimpson.
" **sitchensis** Brandt.
" **grœnlandica** (Fabr.).
" **brevirostris** Dana.
" **lamellicornis** Dana.
" **stylus** Stimpson.

ISOPODA.

Livoneca vulgaris Stimpson.
Cirolana californica Hansen. (?)
Limnoria lignorum (Rathke).
Idotea Wossnessenskii Brandt.
" **resecata** Stimpson.
Ligia Pallasii Brandt.
Pseudione Giardi n. sp.
Argeia sp. (?)
Phyllodurus abdominalis Stimpson.

AMPHIPODA.

Hyperia galba Mont.
Orchestoidea californiana (Brandt).
Polycheria Osborni n. sp.
Mæra dubia n. sp.
Amphithoë humeralis Stimpson.
Amphithoë sp. (?)

COPEPODA.

Cecrops Latreillei Leach.

CIRRIPEDIA.

Pollicipes polymerus Sowersby.
Coronula diadema (L.).

RHIZOCEPHALA.

Sylon sp.

The following additional species occurred in Professor D'Arcy Thompson's collections :

Raphonotus (=**Fabia**) **subquadratus** Dana.
Paguristes turgidus Stimpson.
Echinocerus cibarius White.
Phyllolithodes papillosus Brandt.
Callianassa californiensis Dana.

BRACHYURA.

Cancer productus Randall.

Cancer productus Randall, Jour. Acad. Nat. Sci., Philadelphia, VIII, 116. 1839.

Cancer productus Dana, U. S. Expl. Exp. Crust., I, 156, Pl. vii, fig. 3. 1852.

Cancer productus Stimpson, Boston Jour. Nat. Hist., VI, 461. 1857.

Cancer productus Lockington, Proc. Calif. Acad. Sci., VII, 95. 1877.

One of our specimens has the carapace handsomely ornamented with a complex pattern of narrow red lines on a yellowish ground. The general direction of the lines is longitudinal, interrupted here and there by narrow, more or less symmetrical loopings. A series of three lines runs parallel to the antero-lateral margin, and at the front end converge, together with the adjacent longitudinal lines into the orbit. Lockington (l. c.) describes several color-varieties of this species from Monterey, Cal., one of which is "yellow with narrow red stripes, giving it a zebra-like appearance." This is no doubt the variety before us, though the complexity of the pattern is hardly sufficiently indicated by the epithet "zebra-like." Miss M. S. Rathbun has been good enough to inform me that there are similar specimens in the U. S. National Museum at Washington.

Philyra pisum De Haan.

Philyra pisum De Haan, Fauna Japonica, Crust., 131, Pl. xxxiii, fig. 7. 1850.

Philyra pisum Ortmann, Zool. Jahrb. Abth., f. Syst., VI, 582. 1892.

A single male specimen lacking both chelipeds and some of the ambulatory legs is referred to this species. I have been able to compare it with two specimens dredged in Yokohama Bay by Professor D'Arcy Thompson, and also with three specimens from the Strassburg Museum identified by Dr. Ortmann (l. c.) and sent to us by the great kindness of Professor L.

Döderlein, by whom they were collected in the same neighborhood. The resemblance in both cases is so exceedingly close that in spite of the imperfection of the Puget Sound specimen I have no hesitation in adding *P. pisum* to the list of species inhabiting both sides of the North Pacific. It is recorded from Japan by De Haan and Ortmann, and Mr. R. I. Pocock informs me that there is a specimen in the British Museum from the Philippine Islands.

MACRURA.

PAGURIDÆ.

The great number of closely allied species of *Eupagurus* occurring in the region under consideration, and the imperfect manner in which many of them have as yet been described, render the determination of the species a matter of difficulty in the absence of named specimens for comparison. In this respect I have derived great assistance from a valuable collection of marine invertebrates recently presented to the museum of University College by the Smithsonian Institution. In one or two of the cases where this help was not available I have marked with a query the names of species whose identification did not appear to be beyond doubt. The largest and commonest species of *Eupagurus* in Puget Sound, at first referred to as *E. alaskensis* Benedict in Messrs. Harrington and Griffin's paper on the Invertebrates of Puget Sound (Trans. N. Y. Acad. Sci., 1897, 159) is apparently, as mentioned in Mr. Harrington's paper on commensal nereids (ibid., p. 214), the *E. armatus* of Dana, which, however, Stimpson has identified with the earlier *E. ochotensis* of Brandt (Stimpson, Proc. Acad. Nat. Sci. Phil., 1858, p. 236).

LITHODIDÆ.

Cryptolithodes typicus, Brandt.

Cryptolithodes typicus Brandt, Bull. Phys. Math. de l'Acad. de St. Petersbourg, VII, 175. 1849.

Cryptolithodes typicus Stimpson, Boston Jour. Nat. Hist., VI, 472, Pl. xx, 1857.

The larger of the two specimens in the Columbia University collection agrees with Stimpson's figures and description of the type species, save that the marginal serrations are almost obsolete. The second very small specimen, however, is strikingly different in general appearance. The carapace is approximately triangular, the postero-lateral margins being nearly in a straight line, while the orbital notches are shallower, and the truncated rostrum more prominent than in any other specimens we have seen. A comparison of these and other specimens in the Museum of University College suggests the probability that some at least of the described species of this genus are based on characters varying with the age of the individual.

HIPPOLYTIDÆ.

The generic name *Hippolyte* has been used in its older and wider signification, since Spence Bate's subdivision of the genus (Challenger Rep. Macrura, p. 576) does not appear to be satisfactory.

Hippolyte prionota Stimpson.

H. prionota Stimpson, Proc. Acad. Nat. Sci. Philad., 1864. 153.
H. prionota Kingsley, Bull. Essex Inst. XIV, (1882), 127, Pl. ii, f. 9. 1883.

Kingsley's figure of this species shows the serrated dorsal crest passing in an even curve into the rostrum. In our specimens a slight depression separates the crest from the rostrum, and the latter is more truncate at the tip. Kingsley's figure omits the three orbital spines which are characteristic of the species.

Hyppolyte gracilis Stimpson.

H. gracilis Stimpson, Proc. Acad. Nat. Sci. Philad., 1864. 155.

A single somewhat damaged specimen is probably referable to this species. It differs from Stimpson's description in the fact that the most anterior of the four teeth on the rostrum above is placed considerably in front of the eyes, while the external flagellum of the antennules falls short of the broken tip of the rostrum. As was the case with Stimpson's specimens, no epipod could be discovered on the third maxillipeds.

Hippolyte stylus Stimpson.

H. stylus Stimpson, Proc. Acad. Nat. Sci. Phil., 1864. 154.

Our specimens differ from Stimpson's diagnosis in the fact that the third maxillipeds are slightly longer, reaching a little beyond the extremity of the antennal peduncle to nearly the middle of the rostrum. Some of the smaller specimens show a minute pterygostomial spine, and in this respect resemble the allied *H. camtschatica* Stimpson. (Proc. Acad. Nat. Sci. Phil., 1860. 33.)

AMPHIPODA.

HYPERIIDÆ.

Hyperia galba (Mont.).

Cancer gammarus galba Montagu, Linn. Trans., XI, 4, Pl. ii, f. 2.

Hyperia galba, Sars, Crust. Norway; I—Amphipoda, p. 7, Pl. ii, iii.

Two specimens (♂ and ♀) agree very well with British examples of this somewhat variable species which has not hitherto been recorded from the Pacific.

ORCHESTIIDÆ.

Orchestoidea californiana (Brandt).

(Pl. XXXI, Fig. 1.)

Malorchestia californiana Brandt, Bull. Phys. Math. Acad. Imp. Sci., St. Petersburg, IX, 310–314. 1851.

Orchestia (*Talitrus*) *scabripes* Dana, U. S. Ex. Exp. Crust. II, 860, Pl. 57, f. 4. 1852.

Megalorchestia scabripes Stimpson, Bost. Jour. Nat. Hist. VI, 516. 1857.

M. californiana, Ibid.
Orchestoidea scabripes Spence Bate, Cat. Amph. Brit. Mus. II, Pl. I, f. 3. 1862.
O. californiana, Ibid., p. 14.

Description of Male.—Body robust, glabrous, lower edges of coxal and epimeral plates and all the appendages scabrid with short stiff setæ. Fifth pair of coxal plates having the anterior lobe larger than the posterior, angled below, while the posterior lobe is evenly rounded. Eyes slightly reniform, black. Superior antennæ not reaching the middle of the penultimate joint of the inferior, the three joints of the peduncle subequal, flagellum 9-jointed, hardly longer than half the peduncle. Inferior antennæ longer than the body and very stout. Last joint of the peduncle twice as long as the preceding, increasing in thickness to within a short distance of its distal end, the greatest thickness being nearly one-fifth of the length of the joint. Flagellum more than one and a-half times as long as the peduncle. Palp of maxillipeds three-jointed, second joint expanded inwards as a flat plate, last joint ovate. Inner plate with three conical teeth on distal margin. Anterior gnathopods not subchelate, carpus broader and much longer than the propodus, and having a large tubercle projecting from its lower or posterior edge near the distal end. Propodus cylindrical, having a slight swelling on its lower or posterior face distally. Posterior gnathopods very large, carpus small, propodus ovate, palmar edge oblique and not sharply defined from the posterior edge of hand, bearing a low rounded setose eminence near the articulation of the dactyl, and on the proximal side of this armed with about six short spines with intervening setæ. Dactyl strong, somewhat sharply curved near the base. Claw of second pereiopod bearing at about the middle of its concave side a blunt tooth, from within which springs a small seta. On the posterior legs the tooth is obsolete, but the seta remains. First pair of uropods having the rami subequal, not much shorter than the peduncle, both bearing spines on their outer and inner edges. Last pair of uropods having the single ramus lanceolate and longer than the peduncle. Telson small, triangular, rounded at the tip.

Length, 25 mm., superior antennæ 30 mm.

The identity of our species with that described by Brandt can hardly be doubted on comparing his characteristic though somewhat rough figure of the entire animal. His detailed figures are less successful, and in some points so obviously erroneous that we cannot attribute much weight to the discrepancies they show. The most important character in which our specimens differ from both description and figures is the absence from the palp of the maxillipeds of the minute unguiculate terminal joint on which Brandt lays stress as one of the distinctive characters of his new genus. It seems to us, however, that the resemblance in other details, especially in the antennæ and gnathopods, warrants our assuming an error of observation or possibly an abnormal specimen to account for the difference in the maxillipeds.

Our specimens agree closely with Dana's description and figures of his *Orchestia* (*Talitrus*) *scabripes*, in general aspect and relative proportions, in the shape and size of the two pairs of gnathopods, and in the scabrous character of the limbs. They differ, however, in the length of the last joint of the peduncle of the inferior antennæ. Dana states this joint to be "more than twice the preceding in length," and his figure (of which a very faulty reproduction is given in Cat. Amph. Brit. Mus., Pl. I, f. 3), shows the proportion to be 2.7:1, while the diameter is one-tenth of the length. In our specimens this joint is only very slightly more than twice the length of the preceding, and its diameter is one-fifth of its length. A minor point of difference is that Dana states the outer ramus of the first pair of uropods to be naked. In our specimens both rami are equally furnished with setæ.

Stimpson, who may have examined specimens referred to both species, records them as distinct, stating that Brandt's species differs from Dana's "among other characters in the great length of the fifth epimeral," a point on which Brandt's figure is obscure, while our specimens agree perfectly with Dana's. Stimpson also states that the feet of *M. californiana* are not scabrous. It seems to us, however, that our present knowledge entitles us to regard the species as synonymous, on the probable assumption that the last peduncular joint of the antennæ may vary somewhat in length.

Brandt's species formed the type of his genus *Megalorchestia,* and was transferred by Spence Bate to the synonymous *Orchestoidea* of Nicolet. I have not been able to refer to Nicolet's work, but in his definition of the genus quoted in Stebbing's Challenger report (p. 231), it is stated that the palp of the maxillipeds is four-jointed. Mr. Stebbing, however, informs me that this is an error, the figure given by Nicolet showing that only three joints are present. *Talitronus* of Dana is another synonym of *Orchestoidea* (Stebbing, *op. cit.*, p. 262).

The female of *O. californiana* has not been identified. It seems not improbable, as Mr. Stebbing has suggested to us, that Dana's *O. pugettensis* may prove to be the female, the scabrous character of the legs in *O. californiana* being the only character which stands in the way of this supposition.

ATYLIDÆ.

Polycheria osborni n. sp.

(Pl. XXXII, Fig. 2.)

This species closely resembles *Polycheria antarctica* (Stebbing),[1] but differs from it in the following details :

The dorsal processes of the urosome are much less prominent (Fig. 2, *ur*).

In the maxillipeds the outer plates are longer, nearly equalling the palps and bearing each only about eleven spines on the inner edge (instead of 18–19).

The propodus of the first gnathopods is somewhat differently shaped, the palmar edge, against which the dactyl closes, being very short, not more than one-third the length of the dactyl.

In the second pair of gnathopods the hand is more than twice as long as broad, and the palmar edge extends to about one-half the length of the dactyl.

---

[1] *Dexamine antarctica* Stebbing, Ann. Mag. Nat. Hist. (4) XV, 184, Pl. XV, A. f 1. ; *Tritæta Kergueleni*, Stebbing. Challenger Report Amphipoda, pp. 941–945, Pl. LXXXIII ; *Polycheria antarctica* (Stebb.) Della Valle. Monogr. Gamm, 580.

The coxal plates of the second pair of pereiopods, which in *P. antarctica* resemble those of the first pair in being produced anteriorly into a long sharp spine, are here different, and have the anterior process reduced to a short blunt lobe.

The propodus of the third pereiopods differs in shape from that of *P. antarctica,* the thumb-like process being much less prominent and the anterior and posterior edges nearly parallel.

The first maxillæ have the palp composed of only one joint, but Della Valle has already pointed out (Monogr. Gammarini, p. 579) that Stebbing was misled in ascribing a two-jointed palp to *P. antarctica.*

Length, 7 mm.

8 specimens, all females bearing ova, "in nests in *Amaræcium.*"

The various other species of *Polycheria* which have been described, are probably all referable to one, *P. antarctica* (Stebbing), with a wide distribution in the Southern Ocean (Kerguelen Island, Antarctic Ocean, New Zealand, Australia). The occurrence of a second species in the Northern hemisphere is, therefore, interesting.

At the suggestion of Professor D'Arcy Thompson I have dedicated this interesting species to Professor H. F. Osborn, of Columbia University, New York.

GAMMARIDÆ.

Mæra dubia n. sp.

(Pl. XXXII, Fig. 3.)

Description.—Body moderately slender and compressed, sparsely covered with very small scattered setæ. Lateral lobes of head short, truncate. First pair of coxal plates produced forwards and pointed, slightly less deep than the corresponding segment. Fourth pair nearly twice as long as deep, and about half as deep as the corresponding segment.

Epimeral plates of metasome, each with a slight tooth at the posterior lower corner. Eyes small, dark. Superior antennæ about half the length of the body; first joint of peduncle about one and a-half times as long as the head, short at the base and tapering at the tip, where it is armed below with a small spine; second joint of equal length with the first, much more slender; third joint one-third the length of the second; flagellum about two-thirds the length of the peduncle; accessory flagellum about as long as the last joint of the peduncle, seven-jointed. Inferior antennæ not quite two-thirds the length of the superior; last joint of peduncle three-fourths the length of the preceding and about equalling the short flagellum. Anterior gnathopods of moderate size; hand scarcely broader than, and equal in length to the carpus, ovate in form, the palmar edge oblique and not sharply defined. Second gnathopods large, merus produced into a sharp tooth at its lower distal corner. Carpus triangular, its distal margin equalling in width the adjacent part of the propodus. Propodus oblong quadrangular, twice as long as broad, anterior and posterior margins slightly curved, palmar edge oblique, irregularly serrate, defined by a tooth. Dactyl equalling the palmar edge. Both gnathopods with tufts of long setæ especially on the margins. Last three pairs of pereiopods with the basal joints expanded, ovate, with the posterior edge almost smooth. Last pair of uropods longer than the urosome, rami subequal, more than twice as long as the peduncle.

Length, 13 mm.

The only species of amphipod hitherto described from the west coast of North America which appears to resemble the present form is the *Mæra fusca* of Spence Bate (Proc. Zool. Soc. Lond., 1864, p. 667). The few details given by that writer render the recognition of the species very difficult. It is stated, however, that the palmar edge of the gnathopods is without serrations, a character which would seem to distinguish *M. fusca* from the present species. Mr. Stebbing has called our attention to several other species not very different in appearance from the present. Of these *Gammarus furcicornis* Dana, from the Sooloo Sea, is perhaps the one most closely approaching ours. It differs, however, in the much longer accessory flagellum of the upper antennæ, the shorter and broader hand of the second gnathopods, and the greater hairiness of body and limbs.

Having in view the great difficulty of recognizing with certainty many of the species indicated by the older authors in the difficult group of Amphipoda to which this form belongs, we have judged it best to give a new name to the species described by us, for convenience of reference, at least until it can be shown to be identical with some of the earlier species.

PODOCERIDÆ.

Amphithoe humeralis Stimpson.

Amphithoë humeralis Stimpson, Proc. Acad. Nat. Sci., Philadelphia, 1864, p. 156.

Description.—Body rather compressed. Lateral lobes of head very little prominent, rounded. Anterior pairs of coxal plates about equal in depth to the corresponding segments; fourth pair large, quadrangular, the posterior lobe small and rounded.* Eyes small, rounded, close to lateral lobes of cephalon, pigment dark. Superior antennæ more than half the length of the body; first joint of peduncle stout, about equal in length to the head and to the rather more slender second joint; third joint very small, about one quarter the length of the preceding, and much narrower; flagellum two and a-half times the length of peduncle. Inferior antennæ stout, more than half the length of the superior, last joint of peduncle a little shorter than the preceding, flagellum a little more than half the length of peduncle. Lower lip having the posterior cornu of outer lobe large. Palp of mandible having last joint longer than the preceding, not expanded. Outer lobe of second maxilla broader, but scarcely longer than the inner. Palp of maxillipeds having the first joint slightly produced exteriorly where it forms a distinct shoulder tipped with a tuft of long setæ; outer plates hardly reaching beyond second joint of palp. Gnathopods similar in the two sexes, rather slender, and densely setose. First pair having the carpus longer than the hand, its lower edge convex; propodus quadrangular, about two and a-half times as long as broad, lower edge convex with a shallow concavity distally behind the prominent anterior corner; palmar edge very short, transverse, overlapped by the serrated dactyl. Second pair of gnathopoda having the carpus slightly longer than the propodus, its lower edge produced into a rounded lobe; propodus hardly more than twice as long as broad, shaped as in the first pair, palmar edge somewhat longer but still shorter than the dactyl. First and second pairs of pereiopods similar, basal joint expanded, ovate, twice as long as broad; merus with its anterior margin expanded and regularly arcuate, produced distally in front and overlapping the carpus for one-fourth of its length. Third pair of pereiopods very short, fourth pair hardly extending to end of carpus of fifth pair which are long and slender. Last pair of uropods not reaching beyond the preceding pair, peduncle three times as long as the rami, outer ramus with two strong hooks, inner ramus lamellate, truncate, bearing setæ. Telson triangular, truncate, with a few setæ on each side.

Length, about 26 mm.

The identity of this form with the species observed by Stimpson is at once suggested by his description of the first two pairs of pereiopods, "with the basal joint very large and much expanded, nearly as broad as their epimera; meros-joint in the same pairs small, compressed, with a sharp arcuated anterior margin." The small size of the "subpediform" gnathopoda in both sexes and other less characteristic points are quite in accordance with our specimens. On the other hand, the superior antenna is stated to be "nearly as long as the body." The inferior antenna is "half as long as the body, with its flagellum no longer than the antepenult joint of the peduncle." Though we should probably read "last" or "penultimate" for "antepenult," the length of flagellum indicated is still less than in our specimens. It does not seem to us, however, that these discrepancies are sufficiently important to prevent the identification of our specimens with the species described by Stimpson.

The question whether *Amphithoë humeralis* may be identical with some of the older species is one which it is not possible to answer satisfactorily in the present state of our knowledge. Mr. Stebbing (Chall. Rep. Amph., 351) compares it with Spence Bate's *A. falklandi* (Cat. Amph. Brit. Mus., 237, Pl. XLI, f. 6) and he afterwards (op. cit., p. 1124) notes the resemblance between the latter species and Dana's *A. brevipes* (U. S. Expl. Exp. Crust., II, 941, Pl. 64, f. 5). *A. falklandi*, however, differs, according to Spence Bate's account, from the present species in the fact that the last pair of uropods project much beyond the preceding, while the last two pairs of pereiopoda are said to be subequal. In *A. brevipes* Dana the posterior gnathopods of the male are large and quite different in shape from those of the present species.

Amphithoë sp.

A second species of *Amphithoë* is represented by an imperfect female specimen about 18 mm. long. The coxal plates are very large, about twice as deep as the corresponding segments. Both pairs of antennæ rather slender, upper pair half as long as body, lower about two-thirds as long as upper. Flagellum of lower pair about half as long as peduncle. Gnathopoda stronger than in preceding species, second pair larger than first, hands ovate, palm oblique and defined by a tooth. Second pair of pereiopods (the first are missing) with basal joints not expanded, merus not strongly arched in front. Fourth and fifth pairs of pereiopods rather slender, subequal, with tufts of long setæ especially at tip of propodus. Body and appendages sprinkled with minute reddish-brown pigment spots.

The single mutilated specimen offers no striking characters to differentiate it from several of the other and imperfectly known species, and indeed in this family the distinction of species in the female sex are frequently so obscure that we cannon venture on a more precise determination. It may be noted, however, that in general aspect and particularly in the long setæ of the posterior pereiopods it resembles Dana's *A. filicornis*, from Rio Janeiro, and it may not improbably be the species recorded under that name by Spence Bate from Esquimalt, in J. K. Lord's "Naturalist in Vancouver Island" (from Zoölogical Record for 1866). It differs, however, from Dana's species in the much shorter lower antennæ and deeper coxal plates.

ISOPODA.

CIROLANIDÆ.

Cirolana Californica, Hansen (?).

C. Californica, Hansen, Cirolanidæ, Vidensk. Selsk. Skr., 6 Raekke, Naturvid. og Math. Afd., 3, 1890, p. 338. Pl. iii, f. 2.

The specimen which we refer with some doubt to this species is a male, about 20 mm. long. The body is proportionately narrower (7 mm.) than in Hansen's species. The antennæ hardly reach beyond the second thoracic segment. The last segment of the abdomen hardly broader than long, more acute than in Hansen's figure and with only 14 spines on the tip.

BOPYRIDÆ.

Pseudione Giardi n. sp.

(Pl. XXXIV, Fig. 5.)

Description of Female.—The single specimen, measuring 12 mm. in length, was taken from the right branchial cavity of its host (*Eupagurus ochotensis* (Br.)), and it is, accordingly, a dextral individual (*Bopyre droit* Giard & Bonnier), though the outline of its body seems at first sight to indicate a sinistral curvature, from the concavity of the right margin in the region of the posterior thoracic segments. Closer examination, however, shows that the head and the abdominal region are turned towards the left, and that the pleopods of the right side are longer than those of the left, as in a normal dextral individual, so that the peculiar curvature of the body is, in all probability, merely an accidental variation.

The specimen shows no traces of pigmentation. The dorsal surface is flat or slightly concave, the ventral is convex and is covered, except in the region of the abdomen, by the greatly developed brood-pouch. The dorsal swelling of the cephalic region which marks the position of the stomach (*cephalogaster*), is very slight. An irregularly oval, somewhat convex, area, the "ovarian bosse," is marked off by a groove on each side of the first four thoracic segments on the dorsal surface.

The abdominal segments, six in number, are distinctly separated from each other. The ventral surface of the abdominal segments and of the last two or three thoracic segments is roughened by longitudinal rugæ, which are most marked on the adjacent margins of the segments. These rugæ are neither so conspicuous nor so regularly disposed as in the case of the allied *Palægyge borrei* described by Giard and Bonnier (Bull. Scient. Fr. et Belg., XIX, 68, 1888). The anterior margin of the head is bordered by a narrow membranous expansion (*limbe antérieur*, G. & B.), which shows a distinct notch and several fainter undulations on each side of the middle line. No trace could be discovered on the thoracic segments of the pleural lamellæ, which in *Palægyge* are said to be "rudimentaires et à peine visibles."

The antennules (inner antennæ) are short, conical, composed of three joints and bearing a few very minute setæ at the tip. The antennæ (outer antennæ) are composed of five joints, of which the first is indistinctly marked off from the lower surface of the head; the third is longer and much more slender than the second, the fifth is very minute. The mandibles, which are embraced by the upper and lower lips to form the characteristic "beak" of the *Epicaridea*, are of the usual shape. The first pair of maxillæ appear to be absent. After a careful examination we have been unable to find any distinct rudiments of them, though the triangular areas between the base of the mandibles and the lower lips on each side bear some resemblance to the rudiments of these organs in *Palægyge* (Giard and Bonnier, tom. cit., Pl. V, f. 2). The rudiments of the second maxillæ are to be detected further back on the under surface of the head. Immediately in front of each a relatively large opening leads into a capacious tube lined by an invagination of the chitinous cuticle, the protuberance interpreted as the rudiment of the second maxilla forming the lower or posterior lip of this orifice. Unfortunately, these tubes were not discovered till the soft parts of the head had been removed by caustic potash, so that we are unable to say anything as to their connections inside the body. This is the more to be regretted since we know of nothing analogous to these organs, not only in the *Epicaridea* but even among the *Malacostraca.*

The maxillipeds are similar to those of *Palægyge* but somewhat narrower. Each consists of a flat, roughly quadrangular plate partially divided into two parts by an oblique line. The posterior part has its external angle rounded and pointed as in *Palægyge Borrei,* and the antero-internal angle is produced. The anterior margin of the maxilliped bears a few setæ, and at its inner angle is articulated the small "palp," also setose.

Posteriorly, the lower surface of the head terminates in a freely projecting lamina, the "*limbe postérieur*" of Giard and Bonnier. In the present species this lamina is cut up into a fringe of digitate processes commencing on each side a little way from the middle line and increasing in size outwards. Externally, on each side the lamina is produced into a long process, narrowing gradually from its base to a rounded tip, turned inwards and extending beyond the middle line. In *Palægyge* there are two pairs of shorter processes and no fringe of minute digitations.

The thoracic legs are all similar and of the usual structure. The "adhesive cushions" present on the proximal segments of the first pair in *Palægyge* are here absent. The oöstegites or brood lamellæ were unfortunately injured in the single specimen found. The usual five pairs are present and are much larger than in *Palægyge Borrei*, all the pairs except, perhaps, the third and fourth, overlapping across the median line. The first pair are, as usual, of somewhat complex form. Roughly quadrilateral in shape, the posterior corner is produced into a hook-like process directed inwards. A little behind the middle of its length the lamella is crossed by a transverse fold, forming on its outer or lower surface a deep groove, the anterior margin of which is produced as an overlapping ridge. On the inner, or in its natural position upper, face of the lamella, the fold projects as a strong ridge which for part of its length is fringed with digitate processes. The front edge of the second pair of oöstegites is received into the groove on the lower surface of the first pair. The last two pairs are strongly fringed with setæ on the posterior edge.

Five pairs of biramous pleopods are present, successively diminishing in size posteriorly; those of the right side being, as already mentioned, considerably larger than those of the left. In the first pair the exopodite (lobe *b*, according to the nomenclature of Giard and Bonnier) is roughly quadrilateral in shape and much smaller than the endopodite (lobe *c*), which is long and pointed. In the posterior pairs the exopodite approaches more closely in size and shape to the endopodite. The last segment of the abdomen is very small and bears articulated to its posterior margin a pair of lanceolate lamellæ, of which the right is broader and slightly longer than the left. These lamellæ may possibly represent the sixth pair of pleopods, but a comparison with Giard and Bonnier's figure of the corresponding region in *Palægyge Borrei* suggests that we have here to do with the rudimentary pleural lamellæ (lobe *a* of Giard and Bonnier), which, separated by a distinct suture from the fifth and sixth segments in the last-named species, are here only distinct on the sixth segment. If this view be adopted the sixth pair of pleopods are entirely absent. In all the pleopods the surface of the endopodite is roughened by irregularly transverse rugæ which are most distinct on the anterior pairs.

Male.—A male individual about 3 mm. long was found under the pleopods of the female. The body is symmetrical, lanceolate in outline, the fourth thoracic segment being the widest. A pair of eyes are present near the posterior corners of the head. Both antennules and antennæ are well developed, the former having three, the latter five segments. As in the female, no distinct rudiments of the first maxillæ could be identified. The second maxillæ have the form of rather large, rounded tubercles.

The maxillipeds are present as long slender processes each tipped by a single seta, inserted on each side close to the base of the lower lip. The seven pairs of thoracic feet are all similar and of the usual form, with powerful subchelate terminations.

The six abdominal segments are distinct, regularly diminishing in size posteriorly, and the first five show rudiments of pleopods in the form of slight rounded eminences on the ventral surface. In *Palægyge Borrei*, Giard and Bonnier describe the male as having rudiments of pleopods on the first three abdominal segments only (l. c., p. 70), but in a later paper the same authors speak of the abdominal segments of the male in the genus *Palægyge* as being *all* furnished with these rudiments. (Bull. Scient., XXII, 373. 1890.) The last segment of the abdomen is very small, cordate in form, being very narrow anteriorly and having its hinder margin notched; its greatest breadth is about equal to the length.

Larva.—The brood-pouch of the female was filled with embryos just hatched, and having the form characteristic of the first larval stage of the *Epicaridea.* The head is large and projects in front in a rounded hood-like form. The antennules are in the form of rounded tubercles bearing a number of stout spines among which a narrow pointed process appears to represent the rudiment of the flagellum. The antennæ are about half the length of the embryo, not yet distinctly segmented, and armed at the tip and about the middle of their length with a few spines.

The mouth parts are still in a very early stage, and are difficult to interpret. In the middle the rudiment of the upper lip can be made out, and immediately behind it are a pair of minute lobes in contact with each other in the middle line. Behind this and at some distance from the middle line on each side are three finger-like appendages, the last of these being minutely forked at the tip.

Walz figures (Arb. Zoöl. Inst. Wien. IV, 2, Pl. I, f. 3a) an embryo of *Bopyrina virbii* at a stage apparently corresponding to that of the present specimens. The upper lip and the pair of small lobes close to it are shown, but there are only two pairs of finger-like processes where our specimens show three. The first pair, Walz states, develops into the mandibles, and he suggests that the second pair corresponds to one of the pairs of maxillæ which by fusion give rise to the lower lip (*l. c.*, p. 14). The latter part of his suggestion appears hardly probable. The minute lobes behind the upper lip are not referred to in the text.

The figure which Giard and Bonnier give of the mouth parts of an embryo of *Cancrion miser* (Contr. à l'etude d. Bopyriens, Pl. IX, f. 13), though taken from an earlier stage, corresponds fairly well with our specimens. Two small lobes close to each other, lettered *lb* in their figure, are evidently the same as those which we have lettered *l*. The figure does not seem to be fully discussed anywhere in the text of the monograph, but in the explanation of the plate the interpretation of the letters is given as "première paire d' appendices buccaux (labre)." In their figure of a newly-hatched embryo of *Portunion Kossmanni* (*op. cit.*, Pl. X, f. 1), a pair of appendages exactly similar in shape and position are lettered as mandibles. In *Cancrion* three pairs of appendages follow upon those just discussed. Of these the first two pairs are simple and are interpreted as mandibles and first maxillæ, while the third pair are biramous and are identified as the maxillipeds. In *Portunion* only two pairs of appendages are present in the corresponding position, both simple and lettered as first maxillæ and maxillipeds.

We cannot attempt to reconcile these seemingly contradictory accounts of species which we have not studied, and shall only indicate what seems to be the most probable interpretation of the specimens before us. The rudiments which we have lettered *l* seem, from their position close together in the median line, to be the paragnatha which afterwards fuse to form the lower lip. This leaves three pairs of rudiments to be allotted between the four pairs of appendages from mandibles to maxillipeds, and we may assume one of the pairs of maxillæ to be missing (probably the first pair, which appears to be absent in the adults of both sexes). On the other hand, it is possible that the rudiments *l* may, in spite of their small size and median position, represent the mandibles, in which case the other appendages are satisfactorily accounted for. In either case the pair iv probably represent the maxillipeds, the minute bifurcation at the tip recalling the biramous character of these organs in the embryos of *Cancrion* and of *Cepon* (Giard and Bonnier, Bopyriens, Pl. III, f. 6 and 7).

The completely segmented abdomen of both sexes, the biramous pleopods of the female and the presence of rudimentary pleopods in the male, would refer this species to the genus *Palægyge* as established by Giard and Bonnier in 1888 (Bull. Scient., XIX, 63). The fact that the species infests a pagurid, and the rugosity of the pleopods in the female would place it in the second division of that genus recognized by these authors in 1890 (Bull. Scient., XXII, 373), to which, adopting Stebbing's suggestion (Hist. Crust., 411), we may apply the earlier name *Pseudione*, Kossmann. Of the species enumerated by Mr. Stebbing as referable to the latter genus, three; *P. Fraisci* (Kossmann), *P. Dohrni* (G. & B.), *P. insignis* (G. & B.), appear to be *nomina nuda*, regarding which no particulars save the names of their hosts are recorded. Of *P. callianassæ* Kossmann, only the male appears to be described, and from the account given by Kossmann (Z. f. W. Z., XXXV, 663, Pl. XXXIII, f. 37), and reproduced by Giard and Bonnier (Bopyriens, pp. 77–8), we learn that that species agrees with our form in the presence of rudimentary maxillipeds in the male, though these rudiments are very much smaller in Kossmann's species than in ours. Moreover, rudiments of the first maxillæ, which we have not found, are figured as present in that species.

In *Pseudione Hyndmanni* (Bate & Westwood), described in the British Sessile-eyed Crustacea (p. 243), as *Phryxus Hyndmanni*, from *Eupagurus bernhardus* (L.), the general features of the female appear to approximate very closely to our species. The pleural lamellæ of the abdomen, however, appear to be rounded instead of pointed, and those of the last segment are shorter and broader. The pleopods are smaller and less unsymmetrical.

In *Pseudione confusa* (Norman), from *Galathea dispersa* Bate, described in the above mentioned work (p. 249) as *Phryxus galatheæ*, the brief description and imperfect figures of the female offer no marked distinction from the present species. In the male, however, the abdomen tapers much less rapidly and the last segment is twice as broad as long. The thoracic segments are somewhat more expanded laterally, and the last thoracic is considerably wider than the first abdominal segment. It is stated that "the small conical mouth appears to be protected on each side by a minute 2-jointed foot jaw," but it does not seem probable that the appendages figured are really the maxillipeds.

While the few details available in the case of these species render it impossible to enumerate the characters which distinguish *Pseudione Giardi* from the other members of the genus, it appears to be most closely allied to *P. Hyndmanni*, as was, indeed, to be expected from the nature of its host. Its precise specific delimitation can only be effected when we are in possession of fuller information with regard to the last named and other species.

I have recently received by the kindness of the author a copy of Dr. Hansen's beautiful memoir on the Isopoda of the "Albatross" expedition (Bull. Mus. Comp. Zool., XXXI, 5, 1897), in which he describes and figures *Pseudione galacanthæ* from the deep-sea galatheid *Galacantha diomedeæ*. In spite of the very different host and habitat the new species appears to differ only in trivial characters from our own. Dr. Hansen however recognizes a rudiment of the first maxilla in both sexes where we have only been able to see the membranous interspace between the mandible and the labrum.

Argeia sp.

Two specimens on *Crangon affinis*, De Haan. Both specimens were in very bad condition, having been apparently allowed to dry, and nothing could be made out of their structure. Relying, however, on the principle of MM. Giard and Bonnier, that no species of the *Epicaridea* infests more than one species of host, we may conjecture that these represent a new species of *Argeia* in addition to the two already known from the west coast of America; *A. pugettensis*, Dana, on *Sclerocrangon munitus* and *A. pauperata*, Stimpson, on *Crangon franciscorum*.

Phyllodurus abdominalis Stimpson.

P. abdominalis Stimpson, Boston Jour. Nat. Hist., II, 511. 1857.

Of this interesting and imperfectly known form a large series of both sexes and different stages of growth was obtained. These it is proposed to describe in detail in a later paper. It may be mentioned that the male of this species was recorded and briefly described by Lockington in 1876, in a paper whose title affords no clue to this part of its contents ("Descr. of a new gen. and sp. of Decapod Crustacean," Proc. Calif. Acad. Sci. (1876), 1877, p. 57).

LIGIIDÆ.

Ligia Pallasii Brandt.

Ligia Pallasii Brandt, Conspectus Monogr. Crust. Oniscid. Bull. Soc. Imp. Nat., Moscou, VI, 171. 1833.
Lygia dilatata Stimpson, Bost. Jour. Nat. Hist., VI, 507, Pl. xxii, f. 8. 1857.
Ligia Stimpsoni Miers, Proc. Zoöl. Soc. Lond., 1877. 671.
Ligia Pallasii Budde-Lund, Isop. Terr., 261. 1885.

Of the species described in Budde-Lund's Monograph our specimens approach most closely in the proportions of the uropods to *L. Pallasii* Br., from which they differ only in the much narrower body. Stimpson, however, mentions that the relative width of the body is subject to great variation. The *L. septentrionalis* of Lockington (Proc. Calif. Acad. Sci. (1876), 1877, p. 46), a species not mentioned by Budde-Lund, agrees with our specimens so far as the short description goes, but its distinctness from *L. Pallasii* does not appear to be beyond doubt.

The dimensions of our two specimens are as follows:

Length.	Breadth.	Antenna.	Uropods.
31	16	16	4.5 mm.
21	10	12.5	4 mm.

RHIZOCEPHALA.

Sylon sp.

A single specimen of a *Rhizocephalan*, probably referable to this genus, was in the collections sent me, and I understand that further specimens were obtained. In Messrs. Harrington and Griffin's paper on the Puget Sound Invertebrates (Trans. N. Y. Acad. Sci., 1897, p. 164) a "*Sacculina*" is recorded as occurring on *Sclerocrangon munitus* (Dana). From a sketch kindly sent me by Mr. Harrington I gather that a specimen occurred on a *Pandalus Danæ* Stimpson. In the specimen sent to me, only the abdomen of the host is preserved and this is certainly not that of a *Pandalus* nor of a *Sclerocrangon*, but apparently belongs to some species of *Hippolyte*.

The parasite is attached as usual to the under surface of the third abdominal segment of its host. It has an ellipsoid shape, the longest axis lying nearly parallel to the longitudinal axis of the host's body and measuring about 4 mm. Transversely to the body of the host the parasite has a diameter of 3.4 mm. and its vertical depth is 3 mm. The base of attachment is about 2 mm. in diameter and somewhat nearer the posterior pole. The genital openings could not be detected (Hoek states, in his appendix to the Challenger Report on the *Macrura*, p. 923, that these openings are closed in young specimens), nor was any trace of the mesenteric line visible. The branched "roots" are easily visible inside the body of the host. Hoek states (Ib., p. 924) that in *Sylon*, contrary to what obtains in *Sacculina*, the roots do not reach the intestine of the host, but are, for the most part, confined to the space between the ventral muscles of the abdomen and the integument. In our specimen, however, the roots penetrate further into the body and form a plexus surrounding the intestine.

APPENDIX.

Since the above paper was written I have received from Mr. N. R. Harrington a few Crustacea which had been overlooked in sorting out the Puget Sound material. Among them is a specimen of a small *Slerocrangon* closely resembling but apparently distinct from *S. muricus* (Dana). I believe it to be identical with a species to be described by Mr. A. O. Walker in a forthcoming paper in the Proc. Biol. Soc. Liverpool, and of which Mr. Walker has been good enough to send me a sketch. His specimens were dredged in Puget Sound by Professor Herdman, of Liverpool.

The collection sent me also includes a second specimen of *Sylon*, attached to a *Hippolyte brevirostris* Dana.

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PLATE XXXI.

PLATE XXXI.

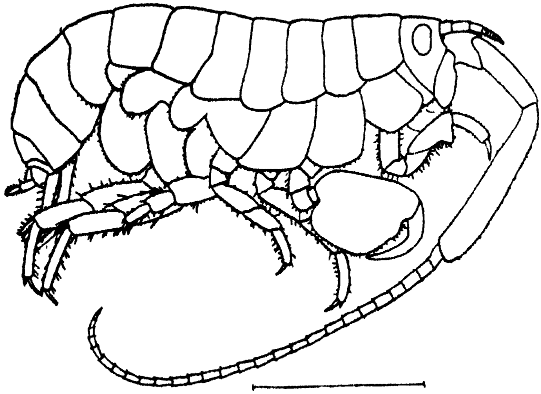
Fig. 1. **Orchestoidea californiana** (Brandt). Male.

REFERENCE LETTERS.

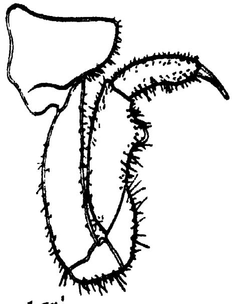
ant′.—Antennules.
ant″.—Antennæ.
as.—Anal style.
bucc.—Mouth parts.
ceph.—Under surface of head.
emb.—Embryo.
en.—Endopodite.
ex.—Exopodite.
gn′, *gn″*.—Gnathopods.
l.—Labium.
la.—" Limbe antérieur."
lp.—" Limbe postérieur."
lbr.—Labrum.
m.—Mandible.
mp.—Maxilliped.
mx′, *mx″*.—Maxillæ.
p', p^2, etc.—Pereiopods.
pl.—Abdomen.
pl^1, pl^{VI}.—Pleural lamellæ.
plp.—Pleopod.
up.—Uropod.
ur.—Urosome.
t.—Telson.

I, *II*, *III*, *IV*.—Mouth parts of embryo (see text).

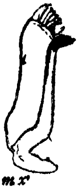
PLATE XXXI.



I



1 gn'



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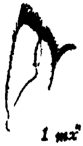
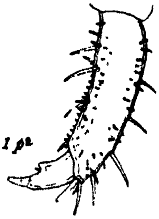
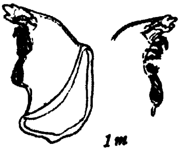


1 mx^{2}



1 p^{2}



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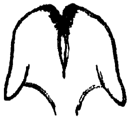

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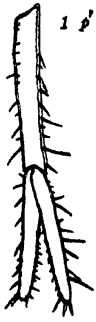
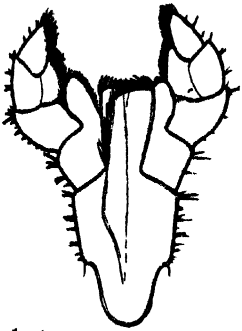


1 p'



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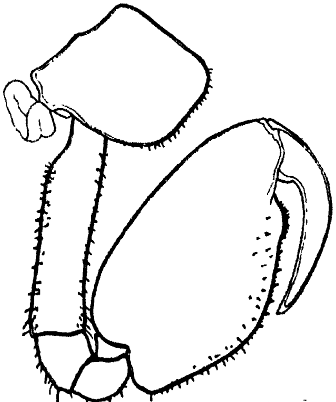
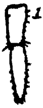


1 gn^{2}



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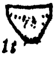


1 t

W. T. C. ad nat. del.

PLATE XXXII.

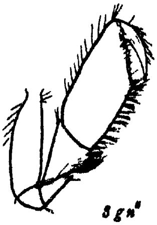
PLATE XXXII.

Fig. 2. **Polycharia Osborni** n. sp. Female.
Fig. 3. **Macra dubia** n. sp.

REFERENCE LETTERS.

ant′.—Antennules.
ant″.—Antennæ.
as.—Anal style.
bucc.—Mouth parts.
ceph.—Under surface of head.
emb.—Embryo.
en.—Endopodite.
ex.—Exopodite.
gn′, *gn″*.—Gnathopods.
l.—Labium.
la.—"Limbe antérieur."
lp.—"Limbe postérieur."
lbr.—Labrum.
m.—Mandible.
mp.—Maxilliped.
mx′, *mx″*.—Maxillæ.
p′, *p*^{2}, etc.—Pereiopods.
pl.—Abdomen.
pl$^{\mathrm{I}}$, *pl*$^{\mathrm{VI}}$.—Pleural lamellæ.
plp.—Pleopod.
up.—Uropod.
ur.—Urosome.
t.—Telson.

I, *II*, *III*, *IV*.—Mouth parts of embryo (see text).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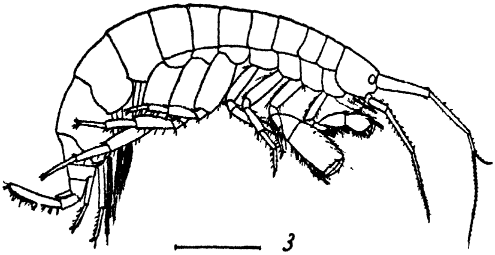
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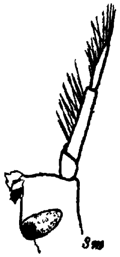
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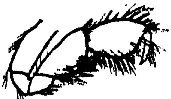
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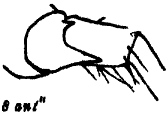
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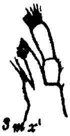
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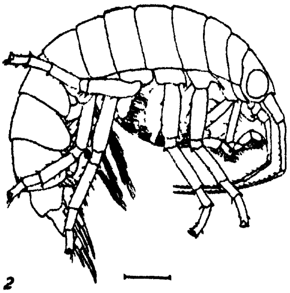
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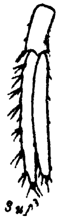
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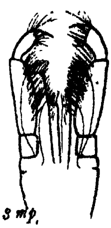
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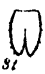
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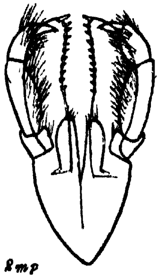
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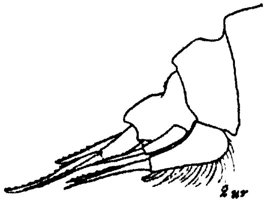
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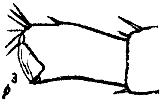
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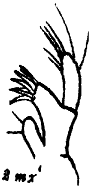
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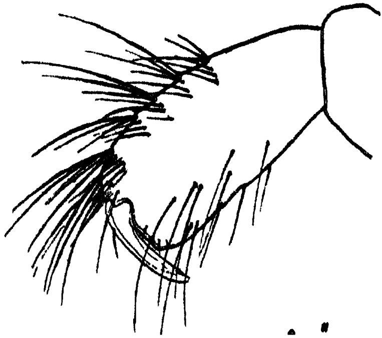
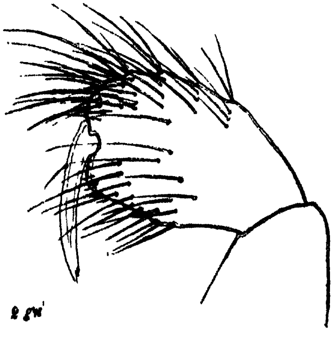



2 gn'

W. T. C. ad nat. del.

PLATE XXXIII.

PLATE XXXIII.

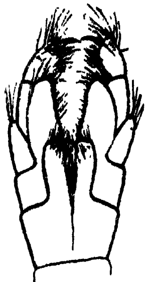
Fig. 4. **Amphithoë humeralis** Stimpson.

REFERENCE LETTERS.

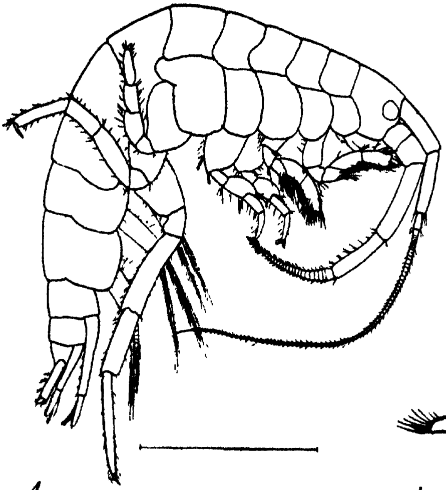
ant′.—Antennules.
ant″.—Antennæ.
as.—Anal style.
bucc.—Mouth parts.
ceph.—Under surface of head.
emb.—Embryo.
en.—Endopodite.
ex.—Exopodite.
gn′, *gn″*.—Gnathopods.
l.—Labium.
la.—" Limbe antérieur."

lp.—" Limbe postérieur."
lbr.—Labrum.
m.—Mandible.
mp.—Maxilliped.
mx′, *mx″*.—Maxillæ.
p′, *p*^{2}, etc.—Pereiopods.
pl.—Abdomen.
pl$^{\mathrm{I}}$, *pl*$^{\mathrm{VI}}$.—Pleural lamellæ.
plp.—Pleopod.
up.—Uropod.
ur.—Urosome.
t.—Telson.

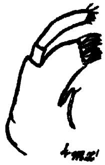
I, *II*, *III*, *IV*.—Mouth parts of embryo (see text).



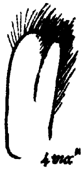
4mp



4



4mx'



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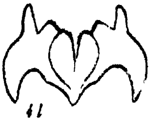

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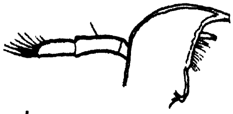

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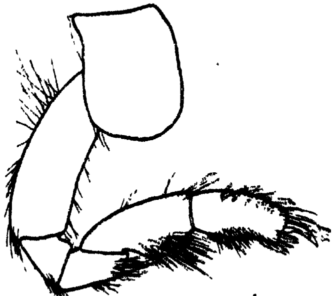
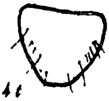


4gn'



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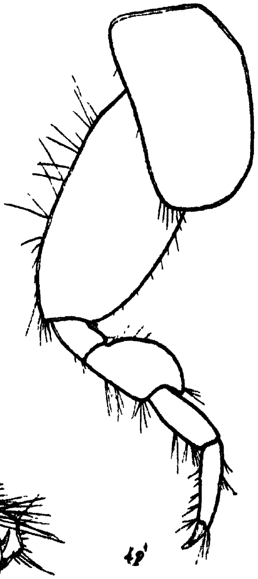
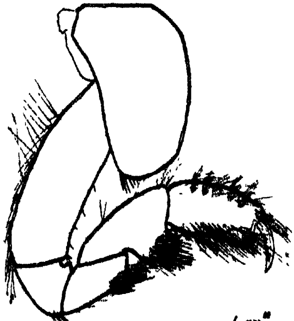


4p'



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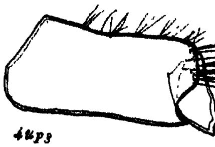


4up3

W. T. C. ad nat. del.

PLATE XXXIV.

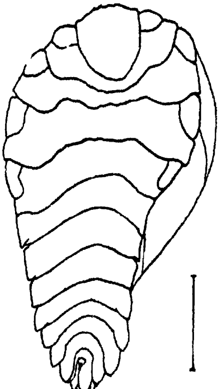
PLATE XXXIV.

Fig. 5. **Pseudione Giardi** n. sp.

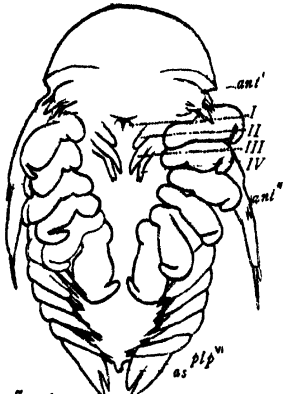
REFERENCE LETTERS.

ant'.—Antennules.
ant''.—Antennæ.
as.—Anal style.
bucc.—Mouth parts.
ceph.—Under surface of head.
emb.—Embryo.
en.—Endopodite.
ex.—Exopodite.
gn', *gn''*.—Gnathopods.
l.—Labium.
la.—"Limbe antérieur."
lp.—"Limbe postérieur."
lbr.—Labrum.
m.—Mandible.
mp.—Maxilliped.
mx', *mx''*.—Maxillæ.
p', p^2, etc.—Pereiopods.
pl.—Abdomen.
pl^1, pl^{VI}.—Pleural lamellæ.
plp.—Pleopod.
up.—Uropod.
ur.—Urosome.
t.—Telson.

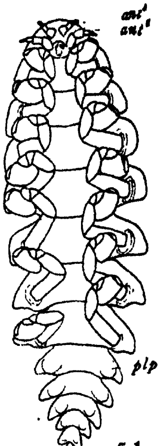
I, *II*, *III*, *IV*.—Mouth parts of embryo (see text).



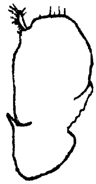
5 ♀



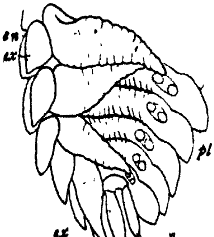
5 emb.



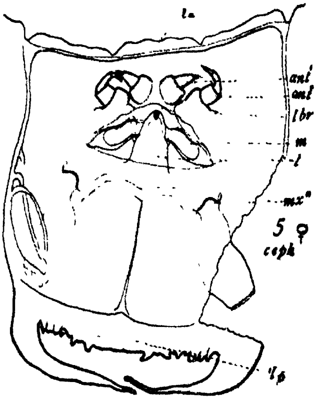
5 ♂



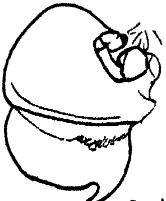
5 ♀ mp



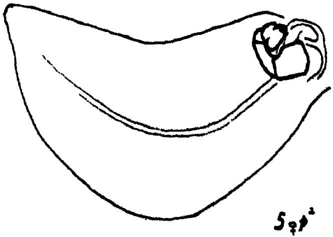
5 ♀ pl



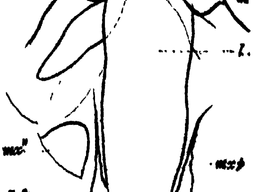
5 ♀ ceph



5 ♀ p^1



5 ♀ p^2



5 ♂ bucc

W. T. C. ad nat. del.

[ANNALS N. Y. ACAD. SCI., XI., No. 14, pp. 293 to 368, September 12, 1898.]

THE PHYSIOLOGY OF SECRETION.

ALBERT MATHEWS.

(Read April 11, 1898.)

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I. INTRODUCTION.

A CRITICISM OF THE SECRETORY-NERVE THEORY.

Nearly fifty years ago it was suggested by Ludwig[48] that secretion was a function of the gland cells controlled by the activity of special nerve fibres. Upon the gland cell, thus emphasized as the prime factor in secretion, and upon its relation to nerve action, most of the subsequent study of the physiology of secretion has been focussed. This study has unearthed such evidences of the truth of Ludwig's hypothesis that to-day few theories of physiology rest upon a foundation apparently firmer, or are more widely accepted, than the hypothesis of secretory nerves. Indeed, the recent discovery,[6] by means of the Golgi and Ehrlich methylen-blue methods, of the remarkably rich distribution of nerves to glands, and of the endings of these nerves about the gland cells, has seemed the final convincing demonstration of the truth of the theory which so many years ago foretold their existence.

The theory of secretory nerves did not long remain in the simple form suggested by Ludwig, for it soon received, at the hands of Heidenhain, a more complete and definite shape. First seriously worked out by him in 1868[21] the theory was further developed in 1878[22] and took its final form in his great treatise on secretion embodied in Hermann's Handbuch der Physiologie in 1880.[23] The Ludwig-Heidenhain theory, thus crystallized by Heidenhain, has been the lens through which the facts of secretion accumulated from 1868 to the present time, have been viewed. This theory may be briefly stated as follows :

Secretion is a specific function of the gland cells controlled by special secretory nerve fibres, acting directly upon these cells. There are two kinds of these nerve fibres : trophic fibres, which render the cell contents soluble ; and secretory fibres, which diminish the resistance to filtration offered by the lumen end of the cell. In consequence of this decreased resistance, the contents of the cell, which are under high endosmotic pressure, escape into the lumen. At the same time the cell imbibes liquid from the lymph space.

Heidenhain, R. Ueber secretorische und trophische Drüsennerven, Pflüger's Archv. f. d. gesam. Physiologie. Bd. XVII, 1878, pp. 60 and following: "The cell is normally under high endosmotic pressure. On nerve stimulation a molecular rearrangement takes place at the lumen end of the cell, so that the resistance to filtration is diminished and water flows out. This flow may be hastened by contractions of the protoplasm, as Kühne observed in the rabbit's pancreas under the microscope. The tension of the water within the cell being thus diminished, water begins to flow out of the lymph and capillaries into the cell. At the end of stimulation molecules are rearranged, the loss of water by the cell ceases, and secretion stops." "The attractive pull on the water comes from the protoplasm of the outer zone."

Before proceeding with the discussion of the evidence upon which this theory rests, it will make the matter clearer to recall the conception of secretion which the Ludwig-Heidenhain theory supplanted. For some of the facts brought forward by these authors are of value, not as direct evidence of the existence of secretory nerves, but because they disprove an alternative earlier conception. The prevalent conception of secretion, before Ludwig's time, was that liquid driven by intra-capillary pressure filtered out through the gland.[48] The chorda tympani was the principal secretory nerve then known, and it was believed to cause secretion by greatly increasing intra-capillary pressure by contraction of the veins or arterioles. The discovery of the vaso-dilator function of this nerve shortly thereafter by Claude Bernard re-emphasized the possibility of a high intra-capillary pressure being an essential cause of secretion. It is not surprising that many physiologists of that day believed that this striking correspondence between vaso-dilation and secretion could not be accidental, and it was natural for them to refer the secretory power of the nerve to its action on the blood vessels.

The first blows against the theory that the vascular system stood necessarily in a causal relation to secretion were dealt by Ludwig and his pupils. They discovered that stimulation of the upper end of the cut cervical sympathetic nerve caused a secretion from the submaxillary gland of the dog,[48] but this secretion, unlike that due to the chorda, was afterwards found to be accompanied by a pronounced vaso-constriction instead of dilation. They found that the pressure capable of being generated by the saliva flowing from Wharton's duct might considerably surpass the pressure of the blood even in the carotid artery. They thus demolished, once and for all, the filtration theory. They found, further, that the temperature of the saliva secreted from the dog's submaxillary might surpass by 1.5 °C., the temperature of the blood in the carotid artery,[49] and as final evidence that the chorda tympani could induce secretion independent of the vasomotor action, they brought forward the observation that stimulation of this nerve still caused a secretion, some minutes after the heart ceased to beat.[61] It is not strange that, in the face of such facts, Ludwig should have felt compelled to assume the secretory activity of the gland cell.

Heidenhain soon added other facts pointing in the same direction. He found that if the blood supply be cut off from the submaxillary gland by compression of the artery the chorda still caused a secretion analogous to the post-mortem secretion after the heart ceases to beat.[21] Giannuzzi[18] discovered that by the injection of sodium carbonate or a dilute solution of hydrochloric acid into Wharton's duct a pronounced vaso-dilation ensued, on stimulation of the chorda, but no secretion. Heidenhain[23] found that quinine sulphate injected into the duct had a similar action, and that atropine[24] effectually paralyzed secretion, while leaving the vaso-dilator power of the nerve unaltered. Heidenhain[25] also discovered, and Langley confirmed his observation, that after the chorda tympani had been paralyzed by the action of nicotine, either injected subcutaneously or applied directly to the submaxillary ganglion, the chorda tympani recovered its secretory function before its dilator function. He observed, also, that after the chorda had been cut and allowed to degenerate for 2–3 days stimulation of the nerve still caused an increase in secretion, without an increase in the flow of blood from the gland's vein. This evidence showed that vaso-dilation might ensue without a secretion, that secretion might take place unaccompanied by vaso-dilation, and that secretion might be caused by stimulating dilator nerves after cutting off the blood supply. If these facts were true vaso-dilation could not be the cause of secretion, and hence that cause must be sought in some other gland element than the blood vessels.

Evidence of a more positive kind of the direct action of nerves upon the gland cells was not long lacking. Heidenhain showed that stimulation of secretory nerves caused well-marked changes in the structure of the gland cells.[21] He discovered that the specific constituents of the secretion were accumulated in the cell during glandular rest, and discharged from the cell during secretion. That these substances were not simply dissolved from the cells by the water stream passing through them he endeavored to show by the fact that on passing from a weak to a stronger stimulation of the chorda tympani, or other dilator secretory nerve, not only the rate, but also the concentration of the secretion increased. Apparently the more rapidly secreted saliva, although in contact with the cell contents for a briefer time, nevertheless dissolved more of them than that more slowly secreted. This obviously would have been impossible if the contents of the cell had not been rendered more soluble by the action of the nerve during the stronger stimulus. He brought forward, also, still more convincing evidence.[22] In the dog's parotid gland stimulation of the cervical sympathetic causes, generally, no secretion, but if this nerve be irritated coincident with the dilator secretory nerve the saliva secreted under the influence of both nerves is more concentrated than that secreted during irritation of the dilator nerve alone. Apparently the sympathetic, though causing no secretion, must, nevertheless, act on the cells, so as to render their contents more soluble. That this effect of the sympathetic could not be due to any possible action of the nerve on contractile tissue of the gland, as suggested by Schiff,[65] Eckhard[13] and others, Heidenhain believed von Wittich[77] had conclusively demonstrated. That the well-known high concentration of the sympathetic saliva could not be referred to the nerve's vaso-constrictor action Heidenhain[22] showed by the fact that, if the gland artery be almost totally compressed, the following chorda saliva was not rendered more concentrated.

These facts undoubtedly furnish strong evidence that the sympathetic and other nerves act on the gland cells, not only increasing the flow of water through them, but also rendering their contents more soluble.

Most of these facts, brought out chiefly in the salivary glands, have been found to be true for other glands. The independence of blood pressure and secretion, the inhibitory action of atropine, and an increase in concentration of the secretion coincident with a more rapid flow, have been observed by Afanassiew and Pawlow,[3] Gottlieb,[19] Pawlow and S.[58] Simonoskaja in the pancreas, stomach and other glands, in which secretion is normally accompanied by vaso-dilation. Sweat may be secreted during vaso-constriction or vaso-dilation, and in the cat's foot, twenty minutes after ligaturing the artery or cutting the leg from the body.[17] The skin glands of amphibia can secrete in the total absence of blood supply.[11] Moreover, of recent years, the importance of the *condition* of the secreting cells, as a factor of secretion, has been clearly realized. The quick paralysis of some secretions during dyspnœa or by the action of drugs has emphasized this factor of secretion. Even in the kidney, where secretion apparently more nearly approaches a filtration, it has been shown that the condition of the capillary, or glomerular epithelium, and the character of the blood, exerts an influence on the secretion.[1] The possibility at once suggests itself that if the condition of the cells is so readily affected by external agents it may be modified by direct nerve action. The very rich nerve supply of many glands and the intimate association of nerve end and gland-cell undoubtedly bring strong confirmation to this supposition.

From this brief outline the extreme complexity of the problem of secretion will be manifest. Some secretions are accompanied by vaso-dilation; others by vaso-constriction. Some may persist twenty minutes after cutting off the blood supply; others are paralyzed within two or three minutes. Some are paralyzed by atropine and quinine; others are not. In the same gland stimulation of one nerve may cause the secretion of a large amount of watery secretion, while stimulation of another nerve causes the secretion of a small amount of exceedingly viscid secretion. There seems, in fact, to be no general rule of secretion true for all glands. The great difference between the phenomena of different secretions suggests that the mechanisms of those secretions may be different in different cases. However probable it may seem, *a priori*, that there is everywhere one fundamental mechanism underlying all these secretions, a decent regard for truth forbids one accepting so far reaching a conclusion, unless it be supported by very strong evidence.

In the present paper, therefore, I wish to reopen the question whether all secretions are due to the activity of the gland cells, and to re-examine the evidence of the existence of nerves acting on those cells. The great theoretical and practical importance of Ludwig's conception is a sufficient excuse for a critical and experimental review, in the light of the physiology of the present day, of the evidence upon which that theory rests. Since the publication of Ludwig's and Heidenhain's work on secretion knowledge has been acquired of vaso-motor changes, osmosis, lymph formation as well as secretion proper, which might, possibly, cause even Heidenhain or Ludwig, if considering the subject at this time, to adopt a somewhat different interpretation of much of this evidence from that heretofore proposed. Such a review seems the more necessary for the reason that special applications of the theory have been, from time to time, questioned, and because, as will be apparent in the course of the following discussion, some of Heidenhain's inferences are unsound, owing to his having neglected to consider possibilities now known to be of importance. His recent extension of the theory to lymph formation, for example, has been seriously disputed by Starling,[68] Cohnheim and others. Starling especially has shown the uselessness of assuming any such secretory mechanism in certain special cases, and has thus thrown doubt upon the truth of the theory as a whole. Langley[37] has questioned the necessity for assuming distinct "trophic" fibres to explain salivary secretion, and for the kidney secretion special inferences of Heidenhain have been challenged by Senator, Adami[1] and v. Sobiranski.[67] The difference in pressure between blood and secretion observed by Ludwig may be readily accounted for on the basis of osmosis quite apart from any cell-activity.[28] The difference in temperature between saliva and blood has been denied by Bayliss and Hill,[5] working with better methods. For some of the facts, also, errors of method greatly diminish the value of the testimony they offer, and some of that evidence depends upon the assumption that all secretions are probably due to the same cause. Hence, whether the theory of secretory nerves is true or not, it must be admitted, I believe, that little of the evidence which has hitherto been presented in support of that hypothesis can be accepted as it stands.

While fully aware, therefore, of the strong *a priori* probablity that nerves may act on gland cells so as to affect osmosis through them, and while appreciating the strength of the evidence that they do so act, I feel myself compelled, for the reasons presented in the following criticisms of that evidence, to question whether secretion is really controlled in this manner.

But not only is the evidence upon which the secretory nerve theory rests inconclusive; there are also certain weaknesses in the theory itself which deserve more attention than they have hitherto received. It is by no means easy to understand how the nerve can affect the cell in such a way as to cause a secretion. The mere discharge of liquid from the cells into the gland lumen would, as pointed out elsewhere, lead to no secretion from the gland ducts. To obviate this difficulty Heidenhain supposed that, while the secretory nerve diminished the resistance of the inner end of the cell, the outer zone imbibed water from the lymph and capillary. The outer zone exerted an attractive pull upon the lymph. By the imbibition of this lymph the secretion was forced along the ducts. This explanation leads at once to difficulties. Not only is the explanation exceedingly hypothetical, but it is difficult to see why, if the pull on the lymph comes from the outer zone, secretion should be slowest after long stimulation, or during paralytic secretion, when the outer zone is at its greatest development, and how secretion can take place at all, or with any rapidity, in glands in which the outer zone has almost, or completely, disappeared, as in mucous salivary glands, the stomach or pancreas, after a long rest. It is also difficult to understand sympathetic secretion, which takes place during a period of vascular constriction. Nor can we ignore the extreme complexity of the theory. The assumption that each, or any, cell of the sub-maxillary gland has acting upon it four totally different nerve ends is, in itself, highly improbable. A further difficulty is encountered when we critically examine Heidenhain's assumption that the trophic and secretory fibres are unequally distributed to the chorda tympani and sympathetic. It seems simple enough to refer the small secretion ensuing on sympathetic stimulation to the presence of a small number of secretory fibres in this nerve, but if it be asked whether these fibres innervate all the cells, or only a portion of them, we are at once plunged into a maze from which there is no way out. If they innervate all the cells we may ask why, if a few fibres suffice, more should be present in the chorda, and why the secretion should not be as copious as the chorda's. If they innervate a part of the cells only, new assumptions must be made to understand why stimulation of the sympathetic should exhaust the constituents of the whole gland. If we abandon the trophic fibres and postulate one sort of fibre only, the secretory, acting on the cell, Heidenhain's facts become largely inexplicable. Furthermore, when Heidenhain[26] assumed secretory nerves to the capillaries he undermined much of the evidence accumulated by him of secretory nerves to glands. For many of the facts of gland physiology might be understood by reference to these capillary nerves. Atropine, for instance, might conceivably prevent secretion by paralyzing the ends of the secretory nerves of the capillaries, thus inhibiting the production of lymph and fluid necessary for secretion.

In the present paper I have considered chiefly the physiology of secretion in the salivary glands. The experimental work has been devoted chiefly to studying the exceptional features of that secretion which have seemed difficult of comprehension on any other than the cellular theory of secretion. I have ventured, however, to bring some other secretions into relation with the conclusions concerning the mechanisms of salivary secretion.

It may prevent confusion and reconcile what might appear to be contradictory statements, to give here the chief conclusion drawn in the present paper. This is, that there is no single mechanism of secretion. In some glands the stored metabolic products are driven out of the cells by the action of muscle, as in Amphibian skin glands and sudoriferous glands; in others they are removed by currents of lymph, which are probably the result of osmosis, as in the pancreas, stomach, salivary glands; in some cases the cells imbibe water until they burst, and their contents rush into the gland-lumen, as in the intestinal cells of Ptychoptera larvæ; in others the inner end of the cell crumbles to pieces, as in the mammalian milk glands. Two, or more, of these mechanisms may coexist in one gland, and it is this which has rendered the physiology of such glands as the salivary so confusing. In the submaxillary gland, for example, I believe we have a muscular mechanism, innervated by the sympathetic; and an osmotic mechanism, innervated by the chorda. The sympathetic, in other words, causes secretion as Eckhard,[13] Schiff,* [65] and others[20] have maintained, by its action on contractile tissue in the gland body, thus mechanically compressing the ducts and alveoli and squeezing out the secretion. The chorda probably causes secretion, by its dilator action on the blood vessels. The following pages present the evidence for these conclusions.

Before proceeding farther it is necessary to define the sense in which the word "secretion" is here used. At present the word has no very definite significance, as it refers to different processes. For the sake of clearness it would be better to designate these various processes by different names. I suggest that, in the future, the word secretion be used to indicate the process of extruding subtances from cells into the lumen of the gland, the process of expulsion from the ducts, and the substances secreted by the gland. By this use of the word cellular secretion will be generally coincident in time with glandular. For the

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[*] Schiff, loc. cit., p. 304, I. "It is probable that the great sympathetic which causes constriction of the parotid vessels causes, at the same time, the tissue of the gland to contract, and that by this contraction the gland empties itself of its contents formed independent of nerve action."

process of the formation of substance by the gland cell—a different process, but one at present included under secretion—I propose the name "Hylogenesis" (Gr. *ὕλη matter* and *γένεσις generation*), and for the substances formed the name "Hylogens." Thus trypinogen, mucinogen, pepsinogen are hylogens. The secretions consist of the hylogens plus water, salts and other substances derived unchanged from the blood. The present paper deals solely with secretion proper. Hylogenesis is considered elsewhere.* This word seems to me preferable to that of "Mesastates," suggested by Mr. J. N. Langley. Ranvier[62] and Van Gehuchten[73] wish to call the process here named hylogenesis, "secretion." This seems to me inadvisable, as thereby cellular secretion would correspond with glandular rest.

The experimental work embodied in this paper has been carried on chiefly in the Physiological Laboratory of Columbia University, and I am particularly indebted to Professor Curtis and Professor Lee both for extending to me facilities of the laboratories and for suggestive criticism. A portion of the work was done in the physiological laboratories of Cambridge University, England, and Marburg University, Germany. I desire to express my hearty appreciation of the courtesy of Professor Michael Foster and Professor Kossel in placing the facilities of their laboratories at my disposal. To Mr. J. N. Langley I am indebted for critical suggestions.

II. SYMPATHETIC SALIVARY SECRETION.

Stimulation of the upper end of the divided cervical sympathetic nerve of the cat, horse, dog, sheep or rabbit generally causes a secretion from the salivary glands. This secretion has everywhere† the same characteristic features, indicating that it is produced in all salivary glands in the same manner. These common features are the following: The saliva reaches its maximum rate of flow in the first 10 or 20 seconds, and then generally ceases, although stimulation lasts for several minutes. If several stimulations follow closely, one upon the other, the amount of saliva secreted at each stimulation rapidly diminishes and often becomes nothing. Stimulation becomes then again effective if the gland be allowed to rest, if the chorda be irritated, or if liquid be injected into the gland duct. Finally, sympathetic secretion is invariably accompanied by vascular constriction, and the saliva, with the doubtful exception of that of the cat,[35] contains more organic matter than that secreted from the same gland under the influence of the dilator nerve.

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* Shortly to appear in the *Journal of Morphology*.

† Except in the resting parotid and submaxillary glands of the dog. See next page.

That there are deviations from the typical course of a sympathetic secretion just sketched need hardly be said. Such deviations are probably due (see p. 309) to the changing fluidity of the saliva. When the saliva is thin, as in the horse, rabbit, cat or sheep, the secretion follows a very typical course; if the saliva be viscous, as in the resting salivary glands of the dog, the latent period is longer, and the secretion persists longer These variations shed a not unimportant light on the mechanism of secretion.

To explain these typical phenomena, assuming the secretory activity of the gland cell, Heidenhain supposed that the sympathetic nerve carried three kinds of fibres: trophic, secretory and vaso-constrictor. The trophic fibres converted large quantities of mucinogen (submaxillary) into soluble mucin, making the juice rich in organic bodies; the secretory fibres caused secretion; the constrictor neutralized the secretory action and stopped secretion. The quick failure of the nerve on successive stimulations was referred to the exhaustion of nerve, nerve end, or gland cell.

The general features of sympathetic secretion seem to me, however, plainly to suggest that the secretion has been driven from the gland by a compression of the ducts and alveoli by some contractile tissue. I wish to consider these features separately, from this point of view, together with experiments bearing on their proper interpretation.

a. THE RATE OF SYMPATHETIC SECRETION.

Experiments I. and II.

Cat and dog. Submaxillary. Animals under ether. Canula in Wharton's duct, connected with a narrow tube graduated in millimeters, 250 mm. = 0.82 cc. Reading's every ten seconds in mm. Chorda-lingual divided in each case. Cervical sympathetic divided and stimulated by tetanic shocks, secondary coil 180–100 mm. The chorda was first stimulated intermittently for an hour, so that the glands were secreting watery saliva.

	CAT			DOG.	
	I	II	III	I	II
1st 10 seconds of sympathetic stimulation	10	9	10	25	17
2d “ “ “ “ “	9	5	6	4	2
3d “ “ “ “ “	0	0	0	3	2
4th “ “ “ “ “	0	0	0	2	1
5th “ “ “ “ “	0 off	0 off	0	2 off	2
6th “ “ “ “ “	0	0	0 off	8	1 off

By inspection of these figures, it is seen that on stimulation the secretion comes suddenly, reaches its maximum rate of flow in the first few seconds, and then quickly subsides. In the cat, it abruptly ceases after 20 seconds. In the dog, probably owing to the greater viscidity of the saliva and the resistance offered to its passage by the fine gland-tubules, it persists slightly throughout the stimulation.

Heidenhain attributes the abrupt cessation of secretion, after a few seconds, to the vaso-constrictor action of the nerve, in consequence of which the secretory mechanism is, as it were, suffocated.[23] That this explanation is incorrect may readily be shown by cutting off the blood by compressing the gland's artery, or by decapitation. In such cases, as the following experiments show, a perfectly typical secretion may ensue on stimulation of the sympathetic, ten or more minutes after ligaturing the artery, or decapitation.

Experiment Va.

(A full account of this experiment is given on page 343.)

Large dog, which had received 3cc. 1% morphine sulphate subcutaneously. Ether given through tracheal tube. Submaxillary dissected free, and remained attached only at the hilus and by its veins. Chorda-lingual and sympathetic cut. Canula connected with tube graduated in millimeters in Wharton's duct. Gland's artery exposed by extirpation of the digastric muscle. Tetanic shocks. Secondary coil at 150. The secretion of the sympathetic is given in mm. at ten second intervals, 250 mm. = 0.82. cc.

TIME.							NERVE STIMULATED.	SECRETION.
h	m	s		h	m	s		
3	25						The artery going to the gland was clamped close to the hilus.	
3	25		–	3	30		Chorda (intermittent)	Copious at first, it gradually ceases.
3	30						"	o
3	32						"	o
3	35						Sympathetic	**16, 3, 2, 2, 0, 0,** off.
3	37						"	o, o, o, 1, o, o, off.
3	40						"	o, o, o, o, o, o, off.
							Interval (see page 317).	
3	42						Artery unclamped. Chorda stimulated intermittently for several minutes.	
4	07	30					Artery clamped.	
4	07	30	–	4	08		Chorda	155
4	08		–	4	09		" (10 sec. int.)	30
4	09		–	4	11	30	"	16
4	12		–	4	13		"	o
4	13		–	4	14		Sympathetic.	**17, 4, 2, 2, 0,** off.
4	15		–	4	17		Chorda	o
4	17	30	–	4	18	15	Sympathetic.	**10, 4, 0, 0.**
4	20						"	o, o, o.
							Interval (see page 317).	
4	25						Sympathetic.	o, o, o.
4	26		–	4	27		Chorda.	o
							Interval (see page 317).	
4	29	30					Artery unclamped. The gland secretes spontaneously Chorda stimulated intermittently.	
4	45	30					Artery clamped.	
4	46	30	–	4	47	30	Chorda	175
4	48	30	–	4	49	30	"	30
4	50		–	4	51		"	10
4	51	30	–	4	52	30	"	2
4	53							o
4	53		–	4	54		Sympathetic	**8, 2, 1, 0.**
4	54		–	4	55		Chorda	o, o, o, o.
4	55	30	–	4	56	39	"	o
4	57		–	4	58		Sympathetic	**0, 4, 3, 0, 0.**
5	02						Artery unclamped.	
5	03		–	5	09		Spontaneous secretion.	
5	09		–	5	10		Sympathetic.	**9, 3, 2, 0, 0.**

Experiment V.

Large dog under morphine and chloroform. Right submaxillary gland prepared. Chorda lingual and sympathetic cut. Each nerve causes a good secretion. Readings as in previous experiments. Canula in Wharton's duct. Secondary coil 150. Tetanic shocks.

TIME.					NERVE STIMULATED.	SECRETION.
h.	m.	s.	h.	m.		
5	49	30			Head cut off as rapidly as possible. Spinal cord and vertebral column not severed.	
5	50	30	– 5	55	Chorda (intermittent)	175
5	55				" (coil 70)	0
5	57				Sympathetic (coil 7)	**40, 20, 6, 2, 0.**
5	58		– 6	10	No stimulation.	
	6	10			Sympathetic	**7, 5, 2, 0, 0.**

Experiment VI.

Dog. Conditions of experiment the same as in Experiment V. Submaxillary. Both nerves active.

TIME.					NERVE	SALIVA SECRETED IN MM.
h.	m.	s.	h.	m		
	4	30			Head completely severed from body.	
4	31	40	– 4	35	Chorda intermittent	65
	4	35	– 4	38	Chorda.	0
	4	38			Sympathetic.	**14, 3, 2, 2, 0.**

The foregoing experiments, demonstrating that a sympathetic secretion may be obtained ten minutes after all fluid and oxygen have been cut off from the gland shows, I think, that Heidenhain was wrong in ascribing the quick normal cessation of secretion during sympathetic stimulation to the nerve's action on the blood vessels. It is obvious that vascular constriction can have nothing to do with such cessation, because the changes produced in a normal gland by vascular constriction, namely, diminution of water and oxygen, have existed in all three experiments at least seven minutes before the nerve was stimulated, and continue during that stimulation without in any way affecting the course of the secretion.

Even a normal gland secreting a very viscous saliva furnishes evidence against the truth of Heidenhain's explanation. In the resting submaxillary of the dog the sympathetic secretion may have a latent period of many seconds and persist for minutes. An instance of such a kind is the following :

Experiment III.

Large morphinized dog, receiving chloroform. Both chorda lingual and sympathetic cut. The submaxillary has not previously been secreting. Sympathetic stimulated by tetanic shocks. Secondary coil 15. Readings every 10 seconds in millimeters as before. *The saliva was extraordinarily viscid.* Total stimulation 2 minutes, 40 seconds. *Latent period 45 seconds.*

Amount of secretion : 0, 0, 0, 0, 5, 7, 7, 5, 5, 5, 4, 5, 5, 4, 4, 3 ; off, 3, 1, 0.

If secretion can begin after 42 seconds, and endure for two minutes, during a period of vascular constriction, as was the case in this experiment, it can hardly be assumed that vasoconstriction is the cause of the normal failure of that secretion within twenty seconds.

Heidenhain seems to have overlooked the fact that a sympathetic secretion may be obtained after cutting off the blood supply, at least five minutes after the chorda becomes inoperative. He referred the quick loss of the chorda's power in these experiments, to the suffocation of the gland cell.* If the loss of the chorda's secretory power is due to the paralysis of the gland cell by suffocation, the sympathetic must cause secretion in some other way than action on the cell, since this nerve causes a normal secretion long after the chorda has been paralyzed.

The quick gush of saliva and its abrupt cessation, as well as the anomalous cases represented by Experiment III, clearly indicate a muscular mechanism of secretion. They are probably to be explained as follows : On sympathetic stimulation the ducts and alveoli are compressed and the liquid in them ejected. If that liquid is thin and runs readily, as in most albuminous glands, for example the parotid and submaxillary of the rabbit, sheep and horse, and the cat's submaxillary, or in mucous glands after long stimulation, the latent period is short, and the saliva is all expelled in from 10–20 seconds. Thereafter, although contraction persists, no more secretion escapes. If, on the other hand, the saliva is viscid, as in the first stimulation of a previously resting mucous gland (submaxillary and parotid of dog), it offers a great resistance in passing through the fine ducts and consequently requires a greater pressure and a longer time to start and to expel. Consequently the latent period is long and the secretion persists for some time. This explains the anomalous cases represented by Experiment III. In cases of very great viscidity, as in the parotid gland of the dog, the resistance may even be too great to be overcome by the compressing strength of the tissues. In this gland stimulation of the symyathetic either causes no secretion at all or very little, unless the saliva in the gland be previously diluted by the action of the dilator nerve. The muscular theory, too, readily explains why a typical sympathetic secretion can ensue in the total absence of blood supply.

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* Heidenhain, R. Hermann's Handbuch der Physiologie V, p. 46 : "Die Ursache der Verlangsamung der Absonderung bei hochgradiger Gefässverengerung oder Gefässverschluss liegt nicht in dem Sinken des Capillardruckes, sondern in der, mit der künstliche Anämie der Drüse verbundenen Verlangsamung des Blutstromes, bei welcher sich das Secretions Material, und namentlich der Sauerstoff für die Drüsenzellen allmälig erschöpft so dass der secretorische Apparat erstickt."

b. THE DECREASE IN THE AMOUNT OF SALIVA OBTAINABLE UPON SEVERAL SUCCESSIVE STIMULATIONS.

If one sympathetic stimulation be followed by several others the amount of saliva obtainable on the second, or following stimulations, is much less than the first, and may be nothing at all.* If, however, the gland be allowed to rest, or if the chorda be stimulated, the nerve again produces a copious secretion upon sympathetic stimulation. This is shown in the following excerpts from experiments on the dog's and cat's submaxillary. Readings in mm. Stimulation in each case for thirty seconds. It is also clearly seen in Experiment VII, p. 311.

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* This phenomenon has, of course, been often described. See among others Langley.[39]

	Cat.	Cat.	Dog.
	I.	II.	
	Amount.	*Amount.*	
1st stimulation	20	16	36
Rest	25 seconds	1 minute.	2 minutes.
2d stimulation	0	6	25
Rest	3 minutes	2 minutes	1 minute
3d stimulation	11	10.5	11
Rest			2 minutes
4th stimulation			10
Rest			1 minute
5th stimulation			11
Rest			1 minute
6th stimulation			2.5
Rest			Chorda stimulated
7th stimulation			25
Rest			2 minutes
8th stimulation			6
Rest			1 min. 40 sec
9th stimulation			4

The great decrease in the amount of saliva obtainable on a second stimulation, closely following a first, even though a minute's intreval of rest elapse, might be explained on Heidenhain's theory, by assuming an exhaustion of secretory fibres, nerve ends or gland cells. Such an assumption is highly improbable. There is, I believe, no other example of a nerve end, or fibre, becoming exhausted by a weak stimulus of a minute's duration. That the secretory fibres of the chorda, their nerve ends and the gland cells are not exhausted or suffocated is shown by the fact that the following chorda stimulation is little, if at all, altered. The phenomena are clearly explicable, on the other hand, if the sympathetic causes secretion by compression of the ducts and alveoli. By the first stimulation the gland is largely emptied of its saliva. If no time be given for the ducts to be refilled, the following stimulation finds less available saliva, or none at all. The nerve appears, in fact, to have become inoperative until, through the resting of the gland, or the action of the chorda, the ducts be again filled. The exhausted element of the gland inferred by Heidenhain is the fluid in the ducts and alveoli.

c. THE AUGMENTATION OF SYMPATHETIC SALIVA.

That the small amount of sympathetic secretion, in the cases just cited, is due to the presence of a small amount of fluid in the ducts and alveoli is indicated by the abnormally large sympathetic secretion, when the amount of liquid saliva in the gland is rendered abnormally large by stimulation of the chorda, or by the action of pilocarpine, nicotine and other drugs.

Langley[39] first observed the augmentation of sympathetic saliva by an immediately preceeding stimulation of the dilator nerve in the dog's parotid and submaxillary and the cat's submaxillary. The following experiments confirming Langley illustrates this augmentation.

Experiment VII.

Dog under morphine and chloroform, sympathetic and chorda cut. Canula in Wharton's duct. Secretion in mm. is given above the line for every 10 seconds, 250 mm. = 0.82 cc. Below the line is indicated the nerve stimulated; s, is the sympathetic; c, the chorda. If no letter is written, it indicates that at these intervals there was no stimulation.

10,	35,	31,	2,	**25,**	4,	3,	2,	2,	8,	6,	4,	**17,**	2,	2,	1,	2,	1,	3,	0
c				s	s	s	s	s				s	s	s	s	s	s		

3,	4,	1½,	1½,	1,	2,	1,	4,	4,	1,	1,	1,	1,	1,	2,	1½,	3,	1,	1,	0,	5,	1,	1,	0
s	s	s	s	s			s	s	s	s				s	s	s					s	s	s

½,	0,	½,	½,	8,	60,	38,	2,	1,	**15,**	3,	1,	3,	3,	2,	2,	3,	2,	4,	1,	1,	2,	2,	1
s				c	c				s	s	s	s						s	s	s			

2,	1,	1,	2,	1,	45,	30,	3,	**25,**	2,	4,	2,	3,	2,	**8,**	1,	1,	1,	2,	———
s	s	s			c			s	s	s	s			s	s	s	s		c. c. c.

18,	7,	3,	3,	2,	½,	4,	**2.**	2,	½,	1,	———————	**39,**	**29,**	4,	0,	0,
s	s	s	s	s	s		s	s	s		Chorda 1 minute	s	s	s	s	

4,	3,	2,	2,	1,	1,	3,	etc.,
s	s	s	s	s			

It will be noticed, in this experiment, that the first secretion of the sympathetic, immediately following the chorda stimulation, is abnormally large, but that the augmentation effect rapidly passes off. The augmented saliva, as Langley pointed out, is more watery than normal and has a shorter latent period. It resembles chorda saliva. A similar watery and copious sympathetic saliva occurs after the injection of nicotine,[24] or pilocarpine,[22] and during paralytic secretion.[42]

This augmented saliva may be explained, assuming that the nerve acts on the gland cell, as follows: If the chorda and sympathetic act as the same gland cells (Heidenhain) it may be said that stimulation of the chorda renders the cells more responsive to a sympathetic stimulation immediately following. If, on the other hand, the chorda and sympathetic innervate different gland cells (Langley), we are forced to the assumption that nerve impulses traverse glands outside of the nerve tracts. "When either nerve is stimulated," Langley says, "there is an irradiation of impulses of less intensity to the cells in the neighborhood of those directly affected; that on stimulation of the chorda tympani the cells connected with it are left for a time in a state of weak excitation, so that irridiation of impulses reaching the gland by the sympathetic is much greater than normal, and these irradiating impulses being weak lead to a more fluid secretion."[39] It can hardly be said, I think, that either of these explanations is satisfactory. That irritability of the gland cells probably has nothing to do with this augmentation, but that it is the simple result of the presence of an abnormally large amount of fluid saliva in the gland is shown by the injection of innocuous fluid into Wharton's duct. By this means we passively distend the ducts and aveoli, without the intervention of cell activities. Following stimulation of the sympathetic causes an augmented secretion. I have tried such experiments only in the case of the dog's submaxillary, a somewhat unsatisfactory gland, owing to the viscidity of the saliva. The experiment, particularly if tried on a fresh gland full of viscous saliva, is not always successful. The cause of the failures has not been investigated, but I suppose they are due to the unavoidable driving into the gland of the viscous saliva and partly to the use of too great pressure in such cases, causing an over-distension of the ducts and a consequent injury to the nerves. The positive results are, however, sufficiently conclusive.

Experiment VIII.

Small dog under morphine and chloroform. Left submaxillary duct and nerves prepared. Nerves cut. The chorda is first stimulated intermittently for an hour. The sympathetic is stimulated each time for 30 seconds. Secondary coil 70. Secretion in mm. as before.

TIME.	NERVE	SECRETION.
h. m. s.		
3 30	Sympathetic	10
3 32	"	4
Inject 1/3cc. 0.6% NaCl solution into Wharton's duct.		
3 34	Sympathetic	**15**
3 36	"	0
3 41	"	0
4 10	"	11
4 11	"	8
4 12 30	"	4
Inject 1/3 cc 0 5% NaCl into duct.		
4 14	Sympathetic	**8**
4 15	"	6

Experiment IX.

Conditions of experiment as in 8. Dog larger. Sympathetic 30 seconds stimulation, unless otherwise indicated.

TIME.	NERVE.	SECRETION IN MM.
h. m. s.		
5 20	Sympathetic	40
5 22	"	15
5 24 -5 25	"	20
5 26	"	10
5 27 -5 27 40	"	20
5 28 -5 28 40	"	18
Inject .4 cc. 0.6% NaCl into duct.		
5 30	Sympathetic	**40**
5 31	"	7
5 32	"	0
Inject .3 cc. 0.6% NaCl.		
5 34	Sympathetic	**11**
5 35	"	2
5 36	"	0
Inject .3 cc. 0.6% NaCl.		
5 38	Sympathetic	**11**

The results of these experiments, in conjunction with those following, are most readily explicable, I believe, on the muscular theory. The augmented saliva, in whatever manner produced, gives fairly conclusive evidence that the nerve causes secretion by compression of the ducts and alveoli. If these are filled with an unusually large amount of fluid saliva an unusually large secretion, characterized by its short latent period and watery character, is secreted. If there be little saliva present, or if it be very viscous, we obtain a small secretion of long latent period and lasting for some time.

(*d*) PARALYSIS OF THE SYMPATHETIC BY EMPTYING THE DUCTS AND ITS RESTORAL TO POWER BY INJECTION OF FLUID INTO THE DUCTS.

Further strong evidence of the muscular action of the sympathetic may be obtained by preventing the passage of fluid into the gland and stimulating the nerve until all available saliva in the ducts has presumably been expelled. The nerve then appears to have lost its action, but it may be shown to be still active by the injection of fluid into the ducts. The passage of fluid into the gland may be prevented either by the use of quinine or by compression of the gland artery.

Heidenhain * showed that if quinine sulphate be injected into Wharton's duct the secretory action of the chorda is ultimately paralyzed, but the gland becomes œdematous. This indicates that, although liquid is present in the lymph spaces, it is prevented in some way from passing through the cell. If, after paralysis of the chorda, the sympathetic be stimulated, a copious secretion is obtained. After a few stimulations, however, the nerve appears to be paralyzed. If that paralysis is only apparent, due to the emptiness of the gland's ducts, we should be able to obtain a secretion on sympathetic stimulation, by the injection into the duct of more quinine sulphate. The following experiment proves this to be the case.

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* Heidenhain, Studien aus Breslau, IV, 1868.

Experiment X.

Large dog. Operation as in other experiments. Secretion in mm. 250 mm.=0.82 cc., s=sympathetic ; c=chorda.

TIME.	NERVE	COIL IN CM.	SECRETION IN MM.
h. m. s.			
12 24	s	15	72
12 25	s	15	12

Chorda stimulated for several minutes, then .5 cc. of saturated solution of quinine sulphate injected slowly into Wharton's duct.

12 37	c	13	0
12 38	c	11	0
12 39	s	11	50
12 40	s	11	27
12 44	s	15	12
12 45	s	15	9
12 47	c	11	0
12 48	c	7	0
12 50	s	14	15
12 54	c	11	0
12 55	s	14	7
12 57	s	13	10
12 59	s	13	3

Inject mixture equal parts 0.6% NaCl and sat. quinine sulphate.

1 03	s	13	24
1 05	s	13	4
1 09	s	12	0
1 10	s	9	1
1 11	s	10	0

Neither nerve produces a secretion, though stimulated from time to time.

4 00	c	8	0
4 01	s	8	0

Inject 0.5 % NaCl into duct.

4 02	s	6.5	32
4 03	s	6	14
4 06	s	6	3
4 09	Inject HCl 0.5% into duct.		
4 10	s	6	9

Chorda ineffective at any strength.

In the foregoing experiment the chorda became completely ineffective at 12:30. The gland, however, was abnormally full of quinine fluid, and the first sympathetic stimulation after the injection consequently gave a greatly augmented secretion at 12:39. Thereafter each stimulation yielded less and less, and finally at 12:59 only 3 mm. were secreted. The ducts may be assumed to be practically empty. Quinine solution was now again injected, and the next sympathetic stimulation yielded again a greatly augmented secretion. Finally at 1:11 the sympathetic failed to yield any secretion, and from then until 4 P. M. was totally ineffective. It would be said, at first sight, that the nerve was paralyzed. Such, however, was not the case, its seeming paralysis being due to the emptiness of the gland. This was shown by the injection of .5 % NaCl solution into the duct. The following stimulation of the sympathetic at 4:02 yielded a very large secretion.

This experiment in two ways furnishes very strong evidence of the muscular nature of the sympathetic secretion. The fact that sympathetic secretion may be obtained long after paralysis of the chorda is very suggestive. Heidenhain* maintains that the chorda secretion is paralyzed by the action of the drug on the gland cells. If this be true, and I see no reason to doubt it, it furnishes very strong evidence that the sympathetic produces its secretion in *some other manner* than action on the gland cell, for the sympathetic secretion is not materially affected long after the gland cells have been completely paralyzed. The fact that the nerve's effect soon passes away, but may be restored by the simple injection of more quinine solution or other fluid into the duct, I believe to be susceptible of but one explanation, *i. e.*, that the nerve causes this secretion by compression of the ducts and alveoli.

A similar phenomenon is witnessed if the gland artery be compressed and fluid thus cut off from the gland. A few stimulations of the sympathetic suffice to render the nerve inoperative, but by injection of fluid into the duct the nerve is shown to be still active.

*Heidenhain, Studien aus Breslau, IV, 1868, p. 85, "so wird die Erregbarkeit der absondernden Elemente bald herabgesetzt und nach kurzer Zeit ganz vernichtet."

Experiment Va (Continued; see p. 305).

TIME. h. m. s.	NERVE	SECRETION IN MM.
3 25	Artery clamped close by the hilus.	
3 30	Chorda	0
3 35	Sympathetic	23
3 37	Sympathetic	0
3 40	Sympathetic	0
	0.2 cc., .5 % NaCl solution injected into duct.	
3 41	Sympathetic	17
3 42	Artery unclamped	
4 07 30	Artery clamped	
4 12	Chorda	0
4 13	Sympathetic	25
4 15–4 17	Chorda	0
4 17 30–4 18 15	Sympathetic	14
4 20	Sympathetic	0
4 23	.3 cc., .5 % NaCl injected into duct	
4 24	Sympathetic	13
4 25	Sympathetic	0
4 26–4 27	Sympathetic	0
4 28	.2 cc., .5 % NaCl injected	
4 29	Sympathetic	8

In this experiment the sympathetic appeared paralyzed at 3:40, 4:20 and 4:26, but the injection of normal salt solution into the duct was followed by a secretion little less than normal, on the next stimulation. In one case twenty minutes after the artery had been clamped, the sympathetic was thus shown still to be active. Heidenhain attributes the loss of the chorda's power to the suffocation and consequent paralysis of the gland cell. (See footnote, p. 308.) As already pointed out (p. 316) this would, if true, show that the sympathetic produces its secretion in some other way than by action on the cell. The fact that the nerve's power may be restored by the injection of innocuous fluid into the ducts is readily explicable on the muscular theory of secretion, but, with difficulty, on the cellular theory.

I found that a similar phenomenon may, at times, be seen in the cat's submaxillary, which has been paralyzed by just sufficient atropin to prevent chorda secretion. As was first pointed out by Langley, atropin paralyzes the sympathetic in the cat, but more atropin is required than to paralyze the chorda. The sympathetic may appear paralyzed, wholly or in part, before it actually is. In this condition gently forcing the secreted saliva back into the gland restores the nerve's power.

Experiment XII.

Cat etherized. Canula in duct of left submaxillary. Both chorda and cervical sympathetic cut. Both nerves active. Inject .1% solution of atropin carefully into femoral vein until chorda just paralyzed. Sympathetic stimulated 30 seconds each time.

Time	Nerve.	Secretion in cc.
h. m. s.		
3 50	Chorda	0.
3 51	Sympathetic	0. 1
3 52	"	0. 1
3 53	"	0. 1
3 54	"	0.05
3 55	"	0.05
3 56	"	0.03
	Blew the secretion gently back into gland.	
3 57	Sympathetic	0.13
4 00	"	0 15
4 06	Inject .1 cc. atropin into femoral vein.	
4 07	Sympathetic	0.10
4 08	"	0.10
4 09	"	0.10
4 10	Sympathetic	.10
	Inject .2 cc. atropin	
4 13	Sympathetic	.07
4 14	"	.01
4 15	"	.03
	Blew saliva into gland.	
4 16	Sympathetic	.25
4 17	"	.05
4 18	"	.04
4 19	"	.02
	Blew .1 cc. saliva back into gland.	
4 20	Sympathetic	.12
4 21	"	.04
4 22	"	.03
	Blew .1 cc. saliva back into gland.	

4 23	Sympathetic	**.14**
4 24	"	.02
4 25	"	.04
4 26	"	.02
	Blew .1 cc. saliva back into gland.	
4 27	Sympathetic	**.13**
4 28	"	.01
4 29	"	.06
4 30	"	.02
4 31	"	.03
	Blew .1 cc. saliva back into gland	
4 32	Sympathetic	**.10**
4 33	"	.02
4 34	"	.05
4 35	"	.04
4 26	"	.03
	Blew back .1 cc. saliva.	
4 37	Sympathetic	**.12**
4 38	"	.04
4 39	"	.01
4 40	"	.04
4 41	"	03
	Blew back .1 cc. saliva.	
4 42	Sympathetic	**.09**
4 43	"	.03
4 44	"	.04
4 45	"	.02
	Blew back .1 cc. saliva.	
4 46	Sympathetic	**.10**
4 47	"	.05
4 48	"	03
4 49	"	.04
4 50	"	.02
	Blew back .1 cc. saliva.	
4 51	Sympathetic.	**.11**
4 52	"	.02
4 53	"	.04
4 54	"	.025
	Blew back .1 cc.	
4 55	S	.075
4 56	S	.025
4 57	S	.04 &c.

The most probable explanation of the apparent failure, partial or total of the sympathetic, in all the immediately preceding experiments, appears to me to be this: That by the injection of quinine, or atropin, or compression of the gland's artery, liquid is prevented from entering the gland. A few stimulations of the sympathetic suffice to expell all, or most, of the available saliva in the gland, and the nerve thereafter appears paralyzed. If, now, the ducts and alveoli be passively redistended by the injection of liquid into the duct the nerve again causes a compression of the duct, and the fluid is again expelled and gives a secretion. This renewed secretion cannot, however, be referred to the action of the gland cell, because the latter has been in one case paralyzed by the action of quinine, and in the other case by suffocation. Nor could it be referred to the action of the cell, even were the latter not paralyzed, for the mere hypothetical taking-up of fluid into the cell from the duct, and its discharge again into the latter, would in no way alter the bulk of fluid in the ducts plus the bulk of the cell. There would, hence, be no pressure to drive the secretion from the gland.

c. THE CHARACTER OF SYMPATHETIC SALIVA.

Evidence that the sympathetic nerve innervates the gland cell has been derived from the character of the sympathetic saliva. This, as is well known, is richer in organic matters than the saliva secreted under the influence of the gland's dilator nerve. This greater richness Heidenhain attributes to the predominance in this nerve of so-called "trophic" fibres, the function of which is to render the stored-up metabolic products of the cell (hylogens) more soluble, and the juice consequently more concentrated. This assumption involves such consequences that by common consent it has been considered the most unsatisfactory part of the Heidenhain theory. It is, however, practically the only probable explanation, with one exception, which has been offered. The exception is the view suggested by Schiff, discussed below.

If the sympathetic simply drives out the saliva already present in the gland the sympathetic saliva must be of the character of that present in the ducts and alveoli at the moment of stimulation. There is evidence that this is the case. That the saliva in the ducts of the dog's parotid is very viscid has been shown by

Langley.[39] Sections show the ducts plugged with a viscous looking mass, and Langley suggests that the saliva is here too thick to be expelled. In one experiment Langley found a dog's parotid which secreted under the influence of the sympathetic 1.3 cc. Concerning this saliva Langley says:[40]

"The saliva was of the most remarkable nature; it formed a thick jelly-like mass; if allowed to collect at all in the canula it could be drawn out as a continuous clot. During the experiment the duct was frequently emptied by pressure to prevent its being stopped up." The saliva contained 7.8 % of organic solids. We can, moreover, artificially alter the fluidity of the saliva in the ducts, rendering it more dilute, by the action of the chorda tympani or pilocarpine. In such cases, as we have seen in speaking of the augmented secretion, sympathetic saliva is almost as thin as chorda saliva. By long stimulation of the chorda, moreover, we may exhaust the soluble constituents of the gland. In such cases it may be presumed that the gland saliva is thinner than normal. It is known that under such circumstances the sympathetic saliva may fall within the limits of density of chorda saliva.* A similar change occurs in paralytic secretions following division of the chorda. The gland then secretes a very thin saliva, and sections show the cells practically exhausted of their mucous. The sympathetic in these causes a very abundant and very watery secretion.

We may obtain still further evidence of the character of the saliva normally present in the ducts of the resting gland by a sudden, strong stimulation of the chorda tympani. The rapid inflow of fluid from the capillaries about the alveoli, taking place under the influence of that nerve, drives out the saliva in the ducts before it has time to become diluted. If we examine this saliva first appearing on chorda stimulation we find it in all respects typical sympathetic saliva. From this Schiff concluded† that sympathetic saliva was nothing more than the saliva normally present in the ducts, formed during glandular rest.

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* Heidenhain, Studien aus Breslau, IV, 1868. After long sympathetic stimulations the saliva becomes "dünnflussig, hell, und dadurch dem chorda Speichel ganz und gar ähnlich."

† Schiff. Leçons sur la Digestion. Tome I., p. 296, 1867; also p. 304.

Schiff found that if the sympathetic nerve of the horse be stimulated the parotid secreted quickly 8–10 volumes of white saliva, and then, as in the cat's submaxillary, secretion ceased. If the horse be fed there ensued a copious, clear secretion of watery cerebral saliva. The gland was now, presumably, full of such saliva. If it be allowed to rest for twenty minutes without secretion on again feeding the horse the first saliva (8–10 volumes) *was typical, thick, white sympathetic saliva.* This was followed by the clear cerebral saliva. Schiff repeated this many times, thus showing that in the interval of rest the gland, uninfluenced by the sympathetic, converts the clear cerebral saliva into typical so-called sympathetic saliva. A similar phenomenon has been described, with a somewhat different interpretation for the dog's submaxillary, by Heidenhain.* I have repeated Schiff's experiment on the dog's submaxillary, fully confirming him. This is shown in the following experiment.

Experiment XIII.

Large dog, morphine and ether. At 10:30 A. M. canula in right Wharton's duct. Sympathetic and chorda-lingual cut. On the first stimulation of the chorda the first saliva was viscid, whitish and filled with corpuscles. The chorda was stimulated until 2 cc. of saliva were secreted. This saliva was thin, clear, typical chorda saliva. Gland rested without secretion until 11:30. Stimulated chorda. *The first saliva was thick, viscid, white saliva.* The gland then secreted 1 cc., clear chorda saliva. Rested until 2:30 P. M. Stimulated the chorda. *A very large amount of typical, sympathetic saliva* appeared first, followed by 2 cc. of watery chorda saliva. Gland rested until 4 P. M. Stimulated chorda. *The first saliva was viscid and contained many salivary corpuscles.* Secreted afterward 1 cc. clear saliva. Rested until 5 P. M. Stimulated the chorda. *The first saliva was again viscid, whitish saliva, filled with salivary corpuscles and lumps.*

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* Heidenhain. Studien aus Breslau, IV, 1868, p. 52. "Die erste Speichel portion war sehr dick, fast gallertartig, reich an Schleimballen wie sie sonst im Sympathicus Speichel vorkommen, und ebenso an Speichelkörperchen die haufenweise bei einander lagen."

This experiment proves that after each stimulation of the chorda, the thin, chorda saliva filling the gland ducts is quickly converted, even in the absence of sympathetic influence, into typical viscid, sympathetic saliva.* It shows, also, that the ducts of the normal, resting mucous gland are filled with saliva, supposed to be characteristic of the sympathetic's action. This observation seems to me to render Heidenhain's assumption of special "trophic" nerve-fibres to account for the character of such saliva, superfluous; and, also, to give additional evidence that sympathetic saliva is nothing more than this "saliva of rest," expelled by compression of ducts and alveoli. The correctness of the latter view is, in my opinion, strongly confirmed by the great variation in character of sympathetic saliva, with a variation of character of the saliva within the gland.

I wish to point out, also, that the influence of sympathetic stimulation upon the composition of the saliva secreted during coincident stimulation of the dilator nerve, upon which special stress has been laid by Heidenhain, is also readily understood on this hypothesis of the nature of sympathetic action. Langley's discovery[39] that the sympathetic produces a secretion from the dog's parotid unless the saliva be too thick for expulsion make Heidenhain's results clear.[22]

Heidenhain found, in harmony with all other observers, that stimulation of the sympathetic usually causes no secretion from the dog's parotid. He concluded from this that the nerve carried no, or few, secretory fibres.† He discovered, however, that if Jacobson's nerve be irritated so as to cause a secretion, and during this irritation the sympathetic be stimulated, the saliva secreted during simultaneous irritation of both nerves was far richer in organic solids than that secreted under the influence of Jacobson's nerve alone.‡ Denying that the sympathetic exerted a secretory effect upon the gland, he considered the secretion to be due to Jacobson's nerve alone. He concluded, therefore, that stimulation of the sympathetic enormously increased the content of organic solids in the cerebral saliva. The sympathetic must hence act on the gland cells so as to render their contents far more soluble. From Langley's results, however, we can safely conclude that the saliva, secreted when both nerves are stimulated, is not pure cerebral saliva, but largely, if not wholly, augmented sympathetic saliva. Like all sympathetic saliva, it is more concentrated than the saliva secreted under the influence of the dilator nerve, because it is expelled without dilution.

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* This is a pretty conclusive reply to the statement of Heidenhain that the simple contact of the water with the hylogens is not sufficient to dissolve them We have here a demonstration that it is sufficient in the total absence of nerve influence.

† Heidenhain. Hermann's Handbuch d. Phys. V, p. 55. "Der Sympathicus des Hundes enthält für die Parotis nur trophische, für die submaxillaris daneben wenige secretorische Fasern."

‡ Heidenhain, Hermann's Handbuch d. Phys. V, p. 55.

f. OTHER EVIDENCE OF THE MUSCULAR NATURE OF THE MECHANISM OF SYMPATHETIC SECRETION.

Very clear evidence, also, has been brought forward by Eckhard,[13] von Wittich[77] and Heidenhain[21] himself that the sympathetic causes at least the major part of its secretion, by a compression of the ducts and alveoli. The parotid gland of the sheep is an albuminous gland, capable of secreting against a pressure of 400–500 m. m. of water (Eckhard). If while secreting against a somewhat lower pressure (200–300 mm.) the cervical sympathetic be stimulated, the water rises suddenly in the manometer for some distance (30–100 mm.). *On ceasing stimulation the secretion rushes back at once into the gland nearly, though never quite, to its former level.* The higher the pressure the more sudden the flow backward. The quick rise at the beginning of stimulation and the abrupt back flow of the secretion at the end plainly suggest that the nerve caused compression of the ducts and alveoli, and thus pressed out the secretion. On ceasing stimulation these structures dilated, and the secretion, being under pressure, rushed back into the gland. I see no other explanation for the back flow, as it takes place too suddenly and at too low a pressure (200 mm. water) to be due to back filtration.

Heidenhain's observation is less striking, but it is similar to the above. (Breslau Studien, p. 69, IV.) In taking the secretory pressure of the dog's submaxillary he stimulated the chorda until the pressure in the ducts was 271 mm. Hg. On ceasing stimulation the manometer gradually fell. *On stimulating the sympathetic the sinking became much slower*, and the manometer remained stationary at 160 mm. On breaking the stimulation the manometer sank gradually to 100. On stimulating the sympathetic it rose to 107, and on chorda stimulation to 271. It gradually fell during following sympathetic stimulation, *but on breaking the stimulation it fell with striking rapidity* (Auftälig beschleunigtes Sinken). Heidenhain thus records for the dog's submaxillary the same sudden back flow on breaking the stimulation of the sympathetic as Eckhard and von Wittich describe in the sheep.

Paradoxical though it may seem, the experiments just quoted of von Wittich and Eckhard have been cited by Heidenhain as conclusive evidence that the sympathetic does not simply drive out the secretion already in the gland. And it is this conviction which led Heidenhain, in the discussion of all experiments involving the sympathetic, to ignore the possibility of its having such an action. Heidenhain believed von Wittich was right in contending that the failure of the manometer to return to its former level on breaking stimulation proved that the amount of saliva in the gland had been increased. It will be instructive to consider von Wittich's explanation of the phenomena of this secretion. von Wittich[77] suggests that the back flow of the saliva is due to the saliva being pushed back into the cells. Let us examine this more closely. von Wittich and Heidenhain assumed that the cells, on stimulation, discharge their stored products into the lumen. Such a process, it need hardly be said, would lead to no secretion from the ducts, as the bulk of the cell would diminish to just the extent that the bulk of fluid in the ducts increases. Hence the bulk of cell plus liquid would remain unaltered. We must, therefore, make either one of two farther assumptions: First, that the alveoli are greatly distended owing to the turgor of the cells. Stimulation of the nerve might conceivably diminish the resisting power of the inner end of the cell, and the secretion be expelled from the cell by intra-cellular tension, and from the ducts by the elastic tension of the distended alveolar wall. Or, second, it must be assumed that, as the fluid flows from the cell, new fluid enters the cell from the rear, so that the cell does not diminish in bulk to an extent aqual to the bulk of secretion it has lost. Either of these assumptions lands us at once in difficulties. If the first be true we cannot understand why the sympathetic secretion should be abnormally large, just in those cases, such as paralytic secretions, or after long-continued chorda secretion, in which the alveoli are not distended and are not presumably under pressure. The second assumption, besides being wholly imaginary, has to explain whence comes the fluid flowing into the cell, and why it should flow in during sympathetic stimulation at a time when there is a pronounced vaso-constriction.

With this difficulty of understanding how the nerve could cause a secretion by action on the cell, let us see how the sudden back flow could be understood. According to von Wittich and Heidenhain the diameter of the alveoli has remained constant. The secretion, manifestly, cannot upon this assumption return into the gland, unless there be a diminution in the combined bulk of the secretion in the ducts and the cells. There will be no such alteration in bulk, however, by the secretion passing into the cell as von Wittich assumes, for the cell will grow to just the amount that the secretion in the lumen diminishes. The only way a diminution in bulk could be brought about is by a back filtration. The fall is, however, much too sudden for this, and takes place at a pressure much less than the gland can sustain without becoming œdematous. It is also impossible to see why on ceasing stimulation the permeability of the gland to back filtration should suddenly increase. Easy though it seems at first sight, therefore, to ascribe such a back flow to a reabsorption under pressure of saliva by the cell, closer inquiry shows that it is impossible to account for this back flow except on the assumption either of a back filtration or that there has been an alteration in the diameter of the alveoli. I maintain with Eckhard that a back filtration is highly improbable, and there remains only the alternative of an increase in the diameter of the alveoli, probably following an active compression.

But if the saliva is simply pressed out, why is it that it does not return to its former level on ceasing stimulation? This was supposed by von Wittich to prove that the nerve increased the amount of saliva in the gland. I fully agree with von Wittich in this contention, but I disagree with him entirely in referring the increase to the action of the nerve on the cell This increase may be readily understood on the muscular theory, without any assumption of nerve activity on the gland cell, as follows: On breaking sympathetic stimulation of considerable duration a temporary vaso-dilation occurs and the ducts and alveoli relax. It takes an appreciable time for the saliva to pass back into the fine tubules, and during this time the cells are absorbing water from the lymph and capillaries. Hence their bulk and the amount of saliva is increased and the saliva is never able to return to its former level. The proof of this is sufficiently clear. That vaso-dilation does occur temporarily on ceasing stimulation of constrictor nerves has often been remarked. I have myself often seen it in the rabbit's ear and in the cat's submaxillary. In the dog's submaxillary I have often seen, also, that coincident with this vaso-dilation a slight secretion may actually ensue (See Expt. VII, p. 311). It is, also, well established that the cells do imbibe fluid and food during or after sympathetic stimulation and thus increase the bulk of undifferentiated protoplasm.

In view of these facts, I believe that von Wittich's and Eckhard's experiments, instead of proving that sympathetic stimution can not possibly be due to compression of the ducts and alveoli, demonstrates that it must be due to such compression; that it is impossible to account for the back flow on any other probable hypothesis, and that the fact that the saliva does not reach its former level is readily understood by reference to the nerve's constrictor action and the temporary vaso-dilation ensuing on breaking simulation. I do not believe that von Wittich ever endeavored to analyze in detail his own explanation, or he must have perceived its impossibility.

g. THE LOCATION AND NATURE OF THE CONTRACTILE SUBSTANCE IN THE GLAND.

The contractile tissue, responsible for the sympathetic secretion, resides neither in the gland capsule nor in the capillaries. Glands dissected free from the capsules secrete normally. The capillaries cannot be held responsible, as Vierheller[71] supposed, because, as one may readily see in the cat's submaxillary, the nerve may be still active on the blood vessels while producing no secretion, and von Wittich[78] records that after curare, the rabbit's sympathetic loses its secretory activity while still active on the blood vessels of the ear. Unna[70] has suggested that the basement membrane is contractile, and this may possibly be the case. There is, however, no evidence of it. That there is smooth muscle about some of the principal ducts of the salivary glands is well-known, but most histologists have failed to find any between or about the alveoli. However, Pflüger[60], and Schlüter[66] have each described isolated fibres, and strands of smooth muscle lying between the alveoli, distinct from the blood vessels, "so that the stroma is not entirely lacking in contractility."

Whether the contractile tissues thus far recognized histologically in the gland are those active in the production of this secretion appears to be doubtful. The physiological evidence is of itself so strong, however, that I believe we can safely assume the existence of such a tissue, even had we no histological evidence of its presence.

h. THE CHANGES IN GLAND CELLS UPON SYMPATHETIC STIMULATION.

The changes in gland cells, induced by stimulation of the sympathetic nerve, are most clearly seen in the rabbit's parotid,[40] less clearly in the dog's parotid, where the nerve causes normally little or no secretion. The changes consist in the diminution in the size of the cell, the discharge of the mucous or secretory products, the formation of new undifferentiated protoplasm and in the nucleus becoming round and moving toward the center of the cell. These changes are identical in kind with, though taking place generally more slowly than, those following stimulation of the dilator nerve or the injection of pilocarpine. Do they indicate the direct action of the nerve on the cell? Although they might be so interpreted, they may be readily understood without any such assumption, as follows: Stimulation of the nerve causes a compression of the cells and thus expels from them their stored-up metabolic products and liquid. By this means the cells discharge their products. On ceasing stimulation the alveoli and ducts relax, and the cells take up water and food from the lymph. The latter process is hastened probably by a temporary vaso-dilation ensuing when the sympathetic stimulation is broken. In virtue of the food, oxygen and lymph thus brought to them the cells form new undifferentiated protoplasm. On several successive stimulations the accumulated metabolic products are largely discharged, the cells become smaller and the nuclei, relieved from pressure, become round and move toward the center of the cells. The same explanation holds also for the changes following stimulation of the dilator secretory nerve, with the exception that the stored products are dissolved out of the cell, instead of being squeezed out, and as vaso-dilation accompanies this secretion the changes take place at a more rapid rate. These changes are discussed more at length in my paper on the Pancreas Cell.*

i. SUMMARY AND CONCLUSION.

The phenomena of sympathetic secretion, which have been considered, could hardly indicate more clearly, I think, the muscular mechanism of that secretion. The sudden gush of saliva; its sudden cessation, however prolonged the stimulation; the diminution in the amount of saliva secreted when the stimulations are rapidly repeated; the apparent paralysis of the nerve when the ducts are empty and its restoral to power if the ducts be passively redistended; the augmentation in volume of the secretion, when the ducts are abnormally full of fluid saliva, and the diminution in amount of secretion when there is little saliva present; the dependence of the character of the sympathetic saliva upon that present in the gland at the moment of stimulation; the back flow of saliva into the gland on stopping stimulation when the gland is secreting against pressure; the presence of smooth muscle in the ducts and between the alveoli—these facts point unmistakably in one direction. A stronger chain of circumstantial and direct evidence that this secretion is caused by compression of the ducts and alveoli by contractile tissue would be hard to imagine. If some of these phenomena are susceptible of explanation upon the hypothesis that the secretion is due to gland cell activity, others of them, *i. e.*, the augmented salivary secretion, the back flow of saliva on breaking stimulation, the paralysis of the nerve when the ducts are empty, and its restoral to power if the ducts be redistended, are explicable, if at all, by that theory, only by means of improbable and unproven assumptions.

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* Shortly to appear in the *Journal of Morphology*.

The surprisingly ready acceptance of the Ludwig-Heidenhain theory of secretory nerves, acting on gland cells, as an explanation of the sympathetic salivary secretion in the face of unmistakable indications of a muscular mechanism, has been due, largely, I believe, to the generally prevalent belief that there is but one mechanism of secretion. That this belief is erroneous, there has long been, I believe, many indications. For there is direct evidence in many glands, such as the poison glands of snakes, the skin glands of amphibia, many unicellular glands, sebaceous and sweat glands, that many secretions are due to muscular action. And in many other glands the phenomena of secretion have shown as clearly that here the mechanism was some other than muscular. There must evidently be at least two different mechanisms, a muscular and some other one. Once the idea that there is but one mechanism of secretion is abandoned, the salivary secretions will be found, I believe, to lose much of their puzzling character.

The facts which Heidenhain urges as showing that the sympathetic produces secretion by action on the gland cell are readily accounted for if the sympathetic cause compression of the ducts and alveoli and vaso-constriction.

III. OTHER SECRETIONS DUE TO MUSCLE ACTION.

Probably many other secretions are due to muscle action.

The unicellular glands of the carp-louse, Argulus foliaceus, are surrounded by muscle fibres. Nussbaum,[55] observing the living glands, states that they are emptied by the contraction of this musculature. Muscle surrounds the unicellular glands in the mantel of Aplysia,[8] and the glandular pedicellaria of the Echinoderms.[34] The gasteropod liver[4] possesses, beneath the serosa, an incomplete musculature, the contraction of which has been watched in the living gland. A similar sheath is found in the livers of Crustacea, land and water Isopods, Amphipods and Decapods.[74]

The poison glands of spiders have their alveoli enclosed in a tunic of spirally arranged muscular fibres.[51] In the salivary glands of Cephalopods[63] the cells rest on connective tissue, which is, in turn, surrounded by muscle fibres. An examination of the physiology of these glands leaves little doubt that the secretion is due to muscular action.[31] The amphibian skin glands are surrounded by a muscular sheath lying between the cells and the basement membrane. There is no doubt from observations on the living glands (Engelmann,[16] Drasch,[11] Ranvier[62]) that this muscle at times contracts, compresses the gland and thus causes a secretion. A similar muscular mechanism prevails in the mucous glands of Petromyzon, in which the cells are bodily extruded.

The poison glands of amphibia and reptilia and others of the salivary glands[76] are provided with their own musculature, or are emptied by surrounding skeletal muscles. Many anal and cloacal glands,[45] sweat[62] and sebaceous glands are provided with a musculature lying between the basement membrane and the cells. There is little doubt that the secretion of sebum is produced by the action of this muscle. The same can be said for the secretion of the oil gland of birds. Probably the most interesting secretion due to muscular action, outside of the salivary glands, is found in the mammalian sweat glands. From the observations of Ranvier,[62] Joseph[29] and others certain secretions of sweat are probably due to the compression of the gland by this muscle. Probably the post-mortem sweat secretions, secretion after closing the artery, or the injection of strychnia are due to this cause. (There is, however, a second sweat mechanism associated with vaso-dilation.)

Many more examples of the muscular mechanism of secretion might be given, but these suffice to indicate the very wide distribution of such a mechanism. Muscular mechanisms are, possibly, more common among the invertebrates, but they play, also, a not inconsiderable part in vertebrate secretions. The vertebrate, however, with its delicately coördinated, closed vascular system, develops a second mechanism, that of osmosis, which we will now consider.

IV. SALIVARY SECRETION ENSUING UPON STIMULATION OF THE VASO-DILATOR NERVE.

That the general features of chorda secretion coincide with the phenomena of osmosis, regulated by the nerve's dilator action, is pointed out briefly on p. 356. I wish here to consider more particularly those facts which have hitherto been irreconcilable with such a theory, and have been generally considered evidence of a special action of the nerve on the gland cell. These facts are the most important evidences of a secretory nerves and so warrant a careful consideration. They are: (*a*) the increase in the percentage of organic solids of a secretion coincident with an increased rate of secretion; (*b*) the action of atropine; (*c*) the chorda-secretion after clamping the artery; (*d*) the action of nicotine.

a. The Increase in the Percentage of Organic Constituents coincident with an Increased Rate of Secretion.

Heidenhain * observed that on passing from a weak to a strong stimulation of the dilator nerve in the fresh submaxillary and parotid gland of the dog, not only was the rate of secretion increased, but also the percentage of solids. He obtained a similar result in the dog's pancreas, Gottlieb[19] in the rabbit's pancreas, and Pawlow and Schumowa-Simanowskaja[58] in the dog's stomach. In the sheep's submaxillary, on the other hand, there was little or no increase in the per cent. of solids on increasing the stimulus.

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* Heidenhain. Hermann's Handbuch der Physiologie V. p. 50. Studien aus Breslau IV, 1868, p. 32.

No. of Stimulation.	Time.		Coil.	Am't. of Secretion.	Rate of Secretion in 1 min.	Solids.	Salts.	Organic Constituents.
	h.	m. m.						
1	9	20-45	315—288	3.5	0.14	0.74	0 22	0.52
2	9	47-51	160—130	3 5	.87	2.10	.56	1.54
3	10	54 5-59	100— 60	3.0	66	2 08	45	1 63
4	10	19-40	264—245	2.8	.11	1.44	36	1 07
5	10	45-48	160—130	3.0	1.00	1.41	.49	0 91
6	10	50-56	80— 65	3.0	.50	1.16	39	0 76
7	11	9-27	270—250	2.5	.13	0 78	.30	0.48
8	11	30-34	150—120	3 1	.77	0 90	38	0.51
9	11	35-44	80— 30	2.8	31	0 79	36	0.42

Heidenhain believed that this increase in solids meant that the cerebal nerve, besides quickening the flow of water through the cells, rendered the cell contents more soluble. How otherwise shall we explain the fact, he asks, that although given a shorter time of contact with these solids, the water passing through the cells, nevertheless dissolves more than during slow secretion. "Die blosse Berührung mit der aus dem Blute ausgeschiedenen Flüssigkeit ist zur Überfuhrung des Schleimes in das Secret nicht ausreichend, denn sonst musste das Secret um so reicher daran sein, je länger die Flüssigkeit in den Drüsenräumen verweilt, d. h. je langsamer die Secretion vor sich geht."[21] He further assumes that the trophic fibers require a stronger stimulus than the secretory. "Das cerebrale Secret wird, so lange die Drüse unermüdet ist, bei Reizverstärkung reicher an organischen Bestandtheilen, weil der Umsatz der organischen Substanzen in den Zellen unter den Einflusse der stärker gereizten trophischen Fasern schneller steigt, als der Wasserstrom unter dem Einflusse der stärker gereizten secretorischen Fasern."[23]

There are two possible fallacies in Heidenhain's argument. One fallacy probably lies in his tacit assumption that the gland secretes as a whole; that the secretion following a strong stimulus is derived from the same alveoli as the secretion following a weak stimulus. The other fallacy is the assumption that all of the organic constituents of saliva secreted from a fresh gland upon a strong stimulus are in solution. The true reason why the dilator-secretory nerve may cause an increase in the organic matter present in a secretion, coincident with an increased rate of flow, in passing from a weak to a strong stimulus, may be the following:

If a very weak stimulus be used, only a portion of the alveoli are aroused to activity. The supply of stored up products (hylogens) in these, becomes soon exhausted and the secretion derived from them is poor in organic constituents. On passing to a strong stimulus, the previously resting alveoli are thrown into activity and the secretion derived from them is rich in organic constituents. It is the secretion from these fresh alveoli, which increases the percentage of organic constituents in the whole secretion. On passing from a long continued weak to a strong stimulus in a fresh gland, one is really passing from an exhausted to a fresh portion of the gland.

Moreover, in Heidenhain's observation there is a second source of error which he has overlooked. Heidenhain treats all of the organic constituents of the rapidly secreted saliva as if they were in solution and considers that the liquid derived from the blood is in contact with the materials to be dissolved, only during the time of its passage through the cell. There can be little question, however, that saliva, and particularly the rapidly secreted saliva of a fresh gland, cannot be considered a true solution, for it contains many bodies in suspension. Heidenhain himself has been one of those to describe the microscopical appearance of the lumps of mucous matter, salivary corpuscles and occasional leucocytes found in this secretion. The presence of these bodies in saliva indicates that the rapidly secreted saliva carries out of the cell not only substances in solution, but viscous masses of mucous matter not in solution. Its swift current is able to transport these masses, while a more slowly flowing secretion is not. Furthermore, in all probability the saliva keeps on dissolving them as it carries them along and hence becomes actually more concentrated, because it is in contact with them really for a longer time than the more slowly secreted saliva and not for a shorter time as Heidenhain thought. Heidenhain made no endeavor to distinguish between the matters in suspension and those in solution.

That any gland functions as a whole, as Heidenhain tacitly assumes in his explanation, can not be maintained.

The whole surface of the stomach, for instance, may be considered as one large gland. It has long been known that secretion can ensue in one spot, and not in another. Heidenhain himself, has called special attention to the marked differences in the condition of the various alveoli in the salivary glands. Even in the resting gland, here and there alveoli will be found possessing the structural features of secretory activity.[22] In the stomach he remarks that some glands show changes on stimulation before others,[23] and I have, myself, repeatedly observed glands in the Newt's stomach close together in very different stages of activity. Kühne and Lea[33] have observed this in the living rabbit's pancreas, a portion only of the gland being normally active. After pilocarpine all the alveoli passed into a condition of activity. In the kidney the independence of the various tubules in secretion has been remarked for the bird's kidney by von Wittich, and for the mammalian kidney by Ribbert,[61] and by Dr. Herter in conjunction with the author. Finally, in the case of the salivary glands, Langley says that even on prolonged activity of the chorda many alveoli show no change. "This is due, in some cases, to fibres escaping stimulation, fibres which leave the lingual later than usual." This histological evidence appears to me to be conclusive with reference to the idea that the gland does not function as a whole, but that the individual alveoli in the secreting gland may be here active, there passive.

The physiological evidence that the foregoing is the true explanation of Heidenhain's observation is hardly less conclusive. We can easily obtain evidence that the secretion obtained during a weak stimulus is derived from a portion of the gland only in the following manner: Let us stimulate the chorda nerve carefully with a very weak current, until a large amount of secretion has been obtained. If this secretion has been derived from the whole gland a stronger stimulus should yield a secretion much less concentrated than a stimulus of equal strength before the weak stimulus. The glands should show, in other words, a considerable exhaustion of the gland products. If, on the contrary, the whole of this secretion has been derived from a portion only of the gland the rest of the alveoli must remain practically unaltered, and a stronger stimulus arousing these should yield a juice, little, if any, poorer in organic matters than was yielded by a stronger stimulus before the weak.

Werther[75] has unintentionally tried this experiment and found the latter possibility to be what actually occurs. A very weak stimulus, with the secondary coil at 300–240 mm., was employed for over three hours, and more than 20 cc. of saliva were secreted. The percentage of organic solids secreted in the slowly flowing saliva steadily fell, but the percentage of such bodies in the saliva secreted on a succeeding stronger stimulus was little if any less, after this long secretion, than it was with an equally strong stimulus before. If, however, a somewhat stronger stimulus was employed, the secretion from a still stronger stimulus was much poorer in organic solids, than the similar stimulus before the weak.

The fact that rapidly secreted saliva is not a pure solution, and the considerations just presented concerning the independence of the alveoli of the gland render this observatoin of Heidenhain of doubtful value as evidence of the existence of secretory nerves.

Moreover, there is good reason for doubting the truth of Heidenhain's statement, in the quotation on page 333, that the liquid derived from the blood is incapable of dissolving the constituents of the cells in the absence of nerve influence. As has already been pointed out, in treating of sympathetic saliva, (page 322), if the thin chorda saliva be simply left in the gland for twenty minutes, or more, it is converted into a dense, viscous fluid having all the characteristics of sympathetic saliva. This conversion takes place with equal readiness whether the gland nerves be intact or divided.

Heidenhain's own explanation, also, will be found on analysis, I believe, to involve such assumptions as to arouse serious doubt of its truth. To explain this phenomenon on the basis of secretory cell activity, he assumed separate "trophic" nerve fibers acting on the cells. He thus necessitated the improbable conclusion, that at least many of the cells of the submaxillary gland received at least four different nerve ends, *i. e.*, trophic and secretory of the sympathetic, and trophic and secretory of the chorda; and at least two entirely different nerve impulses, *i. e.*, trophic and secretory. That such a consequence should not have aroused suspicion in his own mind of the truth of his explanation is difficult to understand.

b. POST-MORTEM CHORDA SALIVARY SECRETION.

Another strong argument that the chorda does not produce its secretion by its dilator action on the blood vessels, but by direct action on the gland cell, has been derived from the so-called post-mortem chorda secretion. Ludwig and Heidenhain found that if the gland's artery be completely closed, or if the head be rapidly cut off, and the chorda at once stimulated, a fairly copious secretion ensued. This secretion was most abundant in the first minute after section, and thereafter rapidly diminished, but a little could still be obtained four, and in some cases five, minutes after decapitation, or compression of the artery. Thereafter the nerve was ineffective. Heidenhain believed this secretion to be due to the action of the nerve on the gland cell, and its rapid failure to lack of oxygen and water. Both Ludwig and Heidenhain believed that by the conditions of the experiment they entirely eliminated the factor of the nerve's vaso-motor action, and hence thought it demonstrative evidence that the secretory and dilator functions of the nerve were independent.

I think it may be questioned, however, whether the conditions of the experiment do entirely obviate the vaso-motor action of the nerve, and whether it is not still possible that this dilation may cause the secretion. It is conceivable that this post-mortem secretion might be due to the flow of blood from the veins and arterioles into the capillaries, owing to the active dilation of the latter during chorda stimulation. This explanation, it is true, necessitates the assumptions that the chorda tympani causes, on stimulation, an active dilation of the capillaries, or veins, as well as of the arterioles, and that that dilation in some manner makes it easier for the liquid to pass out into the secretion. Both of these assumptions are difficult of proof, and in the limited time at my disposal I have not been able to get demonstrative evidence, either of their truth or error. There is some reason to believe, however, that they may possibly be true.

That liquid passes out of the capillaries into the secretion of the submaxillary gland because of an attractive pull exerted upon it by some constituents of the gland cells, has been suggested both by Ludwig and Heidenhain. To the evidence presented in favor of such a view by Heidenhain, I have nothing to add, and in the normal condition of the capillary and gland wall, I presume that the hypothesis is true. Ludwig supposed that during chorda stimulation the attractive pull of the cell was increased, owing to the formation of substances in the cell possessed of a higher endosmotic equivalent. Heidenhain believed that the attraction of the cell for the liquid in the blood was constant, but that on stimulating the chorda, the turgor of the cell diminished owing to the passage of liquid into the gland lumen, and water was thus enabled to enter the cell from the blood. Both of these explanations, as will be noticed, assume that in some manner the effectiveness of the attractive pull of the cell is increased during nerve stimulation and water enters the cells independent of the state of the vascular system. The question which confronts us and which it was supposed this post-mortem secretion settled is this: Does stimulation of the nerve cause secretion by increasing in some manner the attractive pull exerted by the gland cells on the liquid of the blood, or does it indirectly render effective by vaso-dilation an attraction which is constantly exerted by the cell on this liquid? This is a very difficult point to determine. The endeavor has been made to answer this question indirectly by showing that vaso-dilation may ensue without secretion, and secretion without vaso-dilation. But all the evidence which has hitherto been offered, that vaso-dilation may ensue without secretion, and that it alone is incapable of causing secretion, is invalidated by the fact that the conditions of such experiments produce an abnormal gland, or capillary wall, both factors which research on lymph formation have shown to be of importance. Quinine, hydrochloric acid, sodium carbonate, or atropine, drugs which enable vaso-dilation to ensue without secretion, probably alter the permeability of the capillary, or gland cell. So that inferences can be drawn from such experiments as to processes occurring in the normal gland only with the greatest caution. The evidence with the exception of the post-mortem secretion, that the chorda may cause a secretion without vaso-dilation is also unsatisfactory, as pointed out on p. 355. Attention may now be directed, hence, to this post-mortem chorda secretion.

It is probable from the considerations presented on page 338, that the liquid causing this secretion is derived from the blood. Can the chorda tympani act on the blood vessels in the absence of circulation, in such a manner as to facilitate the passage of that liquid from the capillaries to the gland cells? The only possible way in which it might so act, I believe, is by causing an active dilation of the capillaries or veins, as well as of the arterioles. Is there any evidence that the chorda has such an action?

Tiegerstedt[68a] states that the capillaries are contractile but that they have not hitherto been shown to be under nerve control. Roy and Brown have brought forward strong evidence that the capillaries are normally in a state of tonic contraction and that they may actively expand independent of the blood pressure. They observed in the capillaries of the web of the frog's foot that, although blood pressure might be diminished almost to atmospheric pressure, the application for an instant of chloroform to the web caused an enormous expansion of the capillaries. Interesting, also, in this connection, are the observations of von Frey. v. Frey[17] examined microscopically the capillaries of the frog's tongue. He found that on stimulation of the dilator, hypoglossal nerve, a dilation of the capillaries ensued even after the blood supply had been cut off. If the artery be clamped, he observed that the blood streamed out of the capillaries both into the arteries and veins. If, now, the hypoglossal be stimulated the capillaries dilate and blood streams into them from the arterioles and veins. This movement persisted for from one to two minutes after clamping the artery. Furthermore, in experimenting on the blood flow from the veins of the submaxillary gland of the dog during stimulation of the chorda, v. Frey often observed that stimulation of the chorda was followed by a temporary decrease in the rate of flow of blood from the vein, before the ordinary increase. He suggests that this would seem to indicate a widening of the capillary area leading to a back flow of blood from the veins were it not more probable that the increased flow from the dilated arterioles would be more than sufficient to offset this.

These facts justify the conclusion, I believe, that on stimulating the chorda tympani in the severed head, the capillaries of the gland probably dilate, and that blood enters them from the veins.

How such a vaso-dilation might lead to a secretion is not clear, but two possibilities suggest themselves: (1) that the capillaries are thus brought into closer relation with the alveoli, and the constant attraction exerted by the gland contents for the water of the blood is thus rendered effective; or (2) that vaso-dilation may in some way increase the permeability of the capillary wall. The post-mortem chorda secretion can not, I believe, be accepted unconditionally as illustrative of a secretion independent of vaso-dilation, until these possibilities have been shown to be non-existent, or non-essential.

If it shall be found that vaso-dilation of itself is a cause of secretion in the normal gland, and that the gland cell is not the secretory agent, the facts of secretion in the submaxillary gland will probably necessitate the following conclusions, which are not without interest for those studying the physiology of the circulation: (1) That stimulation of the chorda causes an active dilation of the capillaries, as well as a dilation of the arterioles. (2) That the sympathetic is able to overcome the chorda's action on the arterioles, but not its action on the capillaries. This is shown by the following fact: If, during strong stimulation of the sympathetic, the chorda be irritated by a current which by itself is barely able to arouse a secretion, a secretion ensues which is certainly as large, if not somewhat larger, than the chorda alone would cause. Such a weak stimulus of the chorda is, however, unable to neutralize the sympathetic's constrictor action on the arterioles, as shown by the observations of v. Frey. It will be necessary to assume, hence, that the arterioles have remained contracted, while the capillaries have dilated and blood has entered them from the veins producing a secretion analogous to the post-mortem chorda secretion.

I endeavored, in a variety of ways, to obviate with certainty all possibility of the chorda's dilator action. By the injection of supra-renal extract into the circulation I hoped to cause such an intense peripheral constriction as to neutralize the dilator action of the nerve. I am indebted to Dr. R. H. Cunningham for this suggestion. After division of the chorda I injected into the jugular vein the whole of a normal salt extract of two powdered supra-renal capsules of another dog. I found, however, that the injection was followed by a slow constant secretion of what appeared to be sympathetic saliva, and that this secretion was increased at all times by a very weak stimulation of the chorda. Indeed, the chorda caused a larger secretion after the injection than before, probably due to the vaso-constriction in other areas of the vascular system. This result was so discouraging that I did not attempt to repeat it.

Heidenhain remarks that large doses of physostigmin cause such an intense constriction of the arterioles of the gland after division of the chorda that stimulation of the latter nerve is unable to cause either a vaso-dilation, or secretion. Unfortunately, Heidenhain does not give a full account of the experiment. Were it true that the drug produces this effect within three or four minutes of its injection, it would be, I believe, conclusive evidence that secretion can not ensue in the absence of vaso-dilation, and that the nerve does not cause secretion by action on the gland cells; for it is known that the drug does not directly paralyze the hypothetical secretory fibers, or the gland cell. To obtain the details of the drug's action, I injected into the jugular vein of a medium-sized dog 0.1 gr. of physostigmin sulphate. But although the chorda was divided, a spontaneous secretion began which stimulation of the chorda considerably increased. This discrepancy from Heidenhain's results is probably due, I believe, to the impure calabar extract he used.

I endeavored to ascertain whether the presence of blood in the capillaries was an essential condition of the post-mortem secretion by forcing the blood out with air. After ligaturing the carotid artery and placing in it a canula directed headwards I rapidly cut off the head and allowed air to pass into the carotid under a pressure of 100 mm. of Hg. The first experiment gave a positive result. On stimulating the chorda a brief, scanty secretion was obtained which quickly ceased. Examination of the gland showed it to be practically bloodless. In two other similar experiments the post-mortem secretion was greatly reduced in amount and ceased after 1 to 3 minutes, instead of lasting for from 3 to 5 minutes, as normally. The glands in these experiments still contained blood in the veins. The experiments indicate, I believe, that the presence of blood in the capillaries is an essential condition of this secretion. I regret not having been able to bring my experiments to a more satisfactory conclusion, but it is to be hoped that the important bearing of this post-mortem saliva upon the theory of secretion may lead to its being made the subject of careful investigation.

From the following experiments the following conclusions may be drawn relative to this post-mortem secretion:

1. After clamping the gland artery, or cutting off the head, a secretion may be obtained from the submaxillary gland on stimulating the chorda. This secretion is most abundant in the first minutes, and thereafter rapidly diminishes. After four or five minutes no more secretion can be obtained. The total amount of saliva secreted varies from 0.3 to 1.5 cc. (Experiments XVIII, XXII and LXIV.)

2. If the gland be left without stimulation for a minute after decapitation the total amount of saliva obtainable is considerably reduced.

3. If the gland be not stimulated until 3 or 4 minutes have passed a small secretion may be obtained 6 minutes after decapitation. (Experiment XVIII.)

4. If air be blown into the carotid artery, after cutting off the head, the secretion of saliva is reduced in amount and secretion ceases, either abruptly or after 2 to 3 minutes. (Experiments LXIII, LXVI and LXVII.)

5. If defibrinated blood be run under small pressure into the vein of the gland a small secretion may be obtained 20 to 30 minutes after clamping the gland artery.

6. If the blood supply be cut off for 30 minutes, on readmitting blood the arterioles dilate, arterial colored blood issues from the vein at a rapid rate and a spontaneous secretion begins. The rate of this secretion is not changed by stimulation of the chorda in the first minute. (Experiment Va.)

Experiment Va.

Large dog. 3 cc. 1 % morphine sulph. subcut. Tracheotomy. Ether. Canulæ in both submaxillary ducts. Both chordo-linguals and both sympathetics cut. The left vagus subsequently divided also. The right gland is stimulated from time to time. See p. 305. The left is freed from its tunic and is attached only by the hilum. The vein on the upper surface is open and flows continuously. The only blood vessel coming to the gland is the hilum artery. The other artery was tied and cut.

Readings computed in cc.

TIME.						NERVE.	AMOUNT OF SECRETION IN CC.
h	m	s	h	m	s		
3	25					Clamped artery going to gland	
3	25		– 3	30		c	Gradually less.
3	30					c	None.
3	32					c	"
3	35					s	.07

3	37						s	.00
3	40						s	.00
							Inject 5 cc. .5% NaCl into duct.	
3	41						**s**	**.05**
3	42						Unclamped artery.	
3	43	30					c	Active secretion.
3	44						Gland secretions spontaneously .17 cc. per minute.	
							Cut left vagus.	
4	07	30					Clamped artery again.	
4	07	30	–	4	08		Chorda (intermittent).	.50
4	08		–	4	09		c	.18
4	09		–	4	11	30	c	.07
4	12						c	.00
4	13		–	4	14		**s**	**.08**
4	15		–	4	17		c-coil 12	.00
4	17	30	–	4	18	15	**s**	**.05** (very viscid)
4	20						s	.00
4	23						Inject NaCl. 5% into duct.	
4	24						s 30 sec.	**.04**
4	25						c	.00
4	26		–	4	27		s	.00
4	28						Inject ½ cc fluid into duct. Most of it runs out before stimulation.	
4	29						**s**	**.025**
4	29	30					Unclamp artery (red blood rushes out of vein)	
4	30		–	4	31		*Gland secretes spontaneously.*	.1 cc.
4	31		–	4	32		" " "	.12 cc.
4	33	6					c	.30 cc. per minute.
4	35			4	32		Spontaneously secreting.	.08 cc. per minute.
4	37		–	4	38		c 1 mm.	.7 cc
4	38		–	4	45		Spontaneously	.5 cc.
4	45						c	.9 cc. per minute
4	45	30					Clamped artery again.	
4	46	30	–	4	47	30	c (coil 12)	.5
							Gland still slowly secreting spontaneously.	
4	48	30	–	4	49	30	c	.1
4	50		–	4	51		c	.03
4	51	30	–	4	52	30	c	.005 in first thirty seconds, then no more.
4	53		–	4	54		**s**	**.03**
4	54		–	4	55		c	.00
4	55	30	–	4	56	30	c coil 10	.00
4	57		–	4	58		s coil 10	.015
5	02						Unclamped artery.	
5	02	30					c	Readily secretes.
							Blood rushes continuously out of vein a bright red on unclamping the artery.	
5	03		–	5	09		*Gland secretes spontaneously .5 cc.*	
5	09		–	5	10		s	.05

5	13	30				Clamped artery.	
5	13	40	– 5	14	40	c	.5
5	14	40	– 5	17	30	No stimulation.	
5	17	30	– 5	18	30	c	**.03**
5	19		– 5	20		c	.02
5	20					c	.00
5	22		– 5	23		s	.01
5	24					c	.00
5	25		– 5	26		s	.01
5	35					c	00
5	35	30				s	.00
5	36					Unclamped artery. Red blood rushes from the vein.	
5	40					Chorda.	Rapid secretion
						Gland secretes spontaneously	
5	45		– 5	46		Right Sympathetic.	.1 cc.
5	47		– 5	48		Left Sympathetic	.04 cc.
5	49	30				Cut off head as rapidly as possible. Was unable to saw through the vertebral column. All the muscles and skin severed.	
						Right gland.	
5	50	30	– 5	55		Intermittent stimulation of right chorda.	.530
5	55					Chorda (coil 5) muscular contractions	No secretion.
5	57					Right sympathetic.	**.22 cc.**
6	10					Right sympathetic.	**.04 cc.**
5	56					Left gland; no secretion either from chorda or sympathetic.	

Experiment LIV.

Right submaxillary. Chorda and sympathetic cut. Dog under morphine and ether. Tracheotomy. The dog's respirations become very slow, and finally cease without any struggles, and without ether. There was considerable fluid in the trachea.

4.46. Stimulate the chorda while dying, chorda effective until 4.50. The secretion becomes less and less and finally ceases.

I then stimulated the sympathetic and obtained a very copious secretion of .2 cc. No more secretion from either nerve.

Experiment LXIV.

Before cutting. 10 seconds stim. Coil 24. Secretes .79 cc.

Begin to cut at 4.50. 1 minute to sever head completely. No secretion during operation.

h	m	s	h	m		AMOUNT.
4	57	–	4	58	Stimulates 3 times, 10 seconds at a time.	.515 cc
4	59				" 10 seconds	.150 cc.
4	59	30			" 10 "	.021 cc.
					No more secretion.	
					Total time of stimulation 50 seconds. Total amount.	.686 cc.

From beginning to cut to end of chorda effect, 3 m. 30 s.

Experiment XXI.

Before cutting. Coil 20. 10 s. stimulation secretes .55 cc.

Begin to cut at 4.05. 1 minute to sever head completely. No secretion during operation.

h	m	s	h	m			AMOUNT.
4	06		– 4	07	Stimulate 3 times, 10 seconds at a time	1.	.235
						2	.040
					Dog swallows.	3	090
4	07		– 4	08	" 3 times, 10 seconds at a time	1.	.070
						2.	.040
					Swallows	3.	060
4	08	15			Coil to 10, muscular contractions, 10 sec.		.100
4	09				30 seconds stim. off and on (muscle).		.030
4	09	15			No more secretion		
4	10				Coil 4. Heavy contractions (escape of current)		000
					Total time of stimulation, 85 seconds. Total amount,		665 cc.

Time from beginning to cut until end of chorda effect, 4 m. 15 s.

Experiment XVIII.

Before cutting. Coil 11. Stimulate 10 seconds.

Right gland secretes .64 cc. Left gland, .61 cc.

5.24.30 begin to cut head. Head severed in 30 s.

h	m	s	h	m	RIGHT GLAND.		AMOUNT.
5	25		– 5	26	Stimulate 3 times, 10 seconds at a time.	1.	.125
						2.	.100
						3.	.080
5	26		– 5	27	" 4 " " "	1.	.070
						2.	.050
						3.	.020
						4.	.010
5	27		– 5	28	" 40 seconds.		.040 cc
5	28	30			" 10 "		.000

	LEFT GLAND.	AMOUNT.
5 30	Stimulate left chorda 10 seconds.	.070
	next 10 "	.010
5 30 30	" " chorda (strong muscular contractions).	.070
5 31	Left chorda. No more effect except on muscular contraction	

SUMMARY.

Right gland

Total time of stimulation, 120 seconds. Total secretion, 495 cc. From beginning of cut to end of chorda effect, 4 minutes

Left gland.

Total time of stimulation, 20 seconds Total amount, 080 cc. Time from beginning to cut to end of chorda effect (2) 5 minutes, 30 seconds.

Experiment LXIV.

Before cutting. Coil 18. 30 sec. stimulation. Secretes 2.1 cc. Cut head at 4.30, 1½ minutes to sever completely.

h	m	s	h	m		
4	31	40 –	4	36	Intermittent stimulation Secretes	.250 cc.
					No more secretion after 4 35.	
4	38				Stimulate sympathetic for two minutes, secretes	065 cc.

Time from beginning of cut to end of chorda effect 5 minutes.

Experiment XXII.

Before cutting. Coil 18. 10 sec. stim. Secretes .2 cc. Cut at 6.07. 30 seconds to sever head completely.

h	m	s	h	m	s		
4	07	30 –	6	9.		Stimulation, 1st 10 seconds	.225 cc.
						40 seconds stim.	.060 cc.
6	09	20 –	6	19	10	Stimulate coil 18. 30 sec stim.	.150 cc.
6	10	30				Chorda no mre effect	
6	12					Coil to 14. Muscular contractions	.050 cc.
						Total secretion	.375 cc.

Time from cutting till chorda ineffective, 3 m. 30 s.

Experiment LXIII.

Small dog, Irish terrier, under ether. Canula in left Wharton's duct. Tracheotomy. Chorda-lingual nerve cut. Protected electrodes on chorda. Vago-sympathetic not cut. Canula connected with air reservoir in the head end of the left carotid artery.

Before cutting, stimulation of the chorda, with secondary coil at 200, causes a secretion of 0.15 cc. in 10 seconds.

Head rapidly severed at 4.17 P. M. As soon as it was severed I opened the cock, letting air into the carotid. I then stimulated the chorda tympani at 4.18. Stimulation of the chorda causes a secretion of .02 cc. Secretion then stops and no more can be obtained by any strength of stimulus.

Experiment LXVI.

Conditions of the experiment as in Experiment LXIII. Before cutting off the head stimulation of the chorda for 10 seconds with secondary coil at 180 causes a secretion of .17 cc.

Head rapidly severed from body at 3.03. Chorda stimulated at 3.03.45 for 20 seconds. Gland secretes .20 cc. Air then forced into the carotid artery.

3.04.30–3.05.30 stimulation of the chorda with secondary coil at 130 causes .07 cc. Thereafter no secretion with a stimulation of any strength.

Experiment LXVII.

Conditions of experiment the same as in Experiment LXIII. Before decapitation stimulation of the chorda for 10 seconds with secondary coil at 230 yields a secretion of 0.2 cc.

Dog decapitated at 10.49. Air forced into carotid as soon as cutting began. Head severed in 30 seconds.

h.	m.	s.				
10	49	45	Chorda	10 seconds.	Coil 230	0.1 cc.
10	50	30	"	" "	" 200	0.05
10	52		"	20 "	" 180	0.05

Thereafter no more secretion.

Post-mortem examination shows the gland veins to be filled with blood. The air does not seem to have penetrated the gland.

c. THE NATURE OF THE ACTION OF ATROPINE AND PILOCARPINE.

Atropine permits vaso-dilation, on stimulation of the chorda, but prevents secretion. The drug has been supposed to act, not on the gland cell, but on the ends of the secretory nerve fibers. The reasoning for this is as follows: In the dog's submaxillary, atropine paralyzes the chorda secretion, but not the sympathetic. If the sympathetic innervate the gland cell and cause its secretion by action on the latter, the gland cells connected with this nerve have evidently not been paralyzed. As there is no reason to suppose these cells different from those connected with the chorda, it is probable that the cells connected with the chorda have not been paralyzed. But if the gland cells have not been paralyzed, and the dilator action of the nerve remains unaffected, we must assume that there is some third element connected with the nerve which has been paralyzed. This must be the element causing secretion, *i. e.*, the secretory nerve fiber. The latter must be paralyzed at the nerve termination, since, as far as known, atropine does not act on the nerve fibre. This argument is true only for the dog and not for the cat[35] since, in the cat, atropine paralyzes the sympathetic as well as the chorda. The argument, as will be seen, depends on the assumption that the sympathetic causes secretion by action on the gland cells. This, as pointed out, is probably incorrect. The sympathetic produces its secretion by action on contractile tissue. There is, hence, no longer any reason to suppose that the gland cells have not been paralyzed by the drug. How it acts upon the cell is unknown, but the effect of that action is to prevent or diminish the passage of fluid through the cells. The variation in the susceptibility to its action of different glands in the same animal (compare the pancreas, salivary glands and kidneys of dog), or of the same gland in different animals (compare the pancreas of the dog and rabbit) points, I believe, toward an action on the gland cell itself, the variations in its action being due to variation in the chemical composition of the cells.

That atropine does act on the gland cell is, perhaps, indicated also by the action of its great antagonist pilocarpine. Pilocarpine, namely, produces a secretion of sweat two to three weeks after cutting the sciatic of the cat, when the nerve is totally inactive.[72 52 46] Luchsinger,[47] in commenting on this, says that this secretion must be due either (1) to action on the secretory cells themselves, or (2) to the non-degeneration of the nerve ends. The second possibility is impossible since these nerve ends are not provided with nuclei. A similar secretion may be obtained in the dog's salivary glands, fourteen days after cutting both chorda and sympathetic. The evidence is here not so conclusive since the submaxillary ganglion does not degenerate. In the sweat secretion, however, I believe the evidence is fairly strong that pilocarpine does act directly on the gland cell. It thus strengthens the evidence that atropine also acts on the cell.

There is also reason for believing that atropine acts in some manner on the capillary wall, thus reducing, or preventing the transudation of lymph. It might, in this way effect secretion from glands. This possibility has not received the attention it deserves.*

The evidence that atropine checks lymph transudation is as follows:

If atropine permitted the transudation of lymph normally ensuing on vaso-dilation, it would be expected that, after its injection, stimulation of the chorda would render the submaxillary gland œdematous, since fluid no longer passes into the secretion. Quite the contrary is the fact. I have repeatedly stimulated the gland all day, after the injection of atropine, without producing a trace of œdema. Heidenhain[25] himself says: "After atropine on stimulation of the chorda tympani no increase in lymph flow occurs, even when during stimulation of the chorda the medulla is stimulated and the blood pressure greatly increased." Brunton in commenting on this says: "It appears to me that this circumstance can hardly be explained otherwise than by supposing that atropin not only paralyses the secretary fibres of the chorda, but acts upon the blood vessels in such a manner as to greatly diminish or prevent the exudation which would usually take place from them into the lymph spaces."

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* Heidenhain's reasons for rejecting the possibility that atropine checks lymph transudation and thus secretion will be found in Hermann's Handbuch. A striking instance of failure to consider this possibility is the following quotation from Langley:

"Atropine prevents the stimulation of the hilum from producing a secretion. Nicotine does not do this, therefore, atropine acts upon structures more peripheral than those acted upon by the nicotine. Since nicotine acts on nerve cells, and atropine does not act on gland cells, atropine must produce its paralyzing result by action on the secretory nerve endings."

Heidenhain[23] supposed that lymph normally left the blood vessels on account of the secretory pull exerted by the gland cell. Atropine prevented lymph transudation by paralysis of the secretory chorda nerve ends. He was led to this conclusion chiefly by the following facts: (1) No more lymph normally leaves the blood vessels than passes into the secretion, and (2) if one inject 4.9% solution of sodium carbonate, 0.5% hydrochloric acid or quinine sulphate into Wharton's duct the chorda's secretory power is annihilated, but on stimulation the gland becomes highly œdematous. If, however, atropine be injected into the blood before the chorda is stimulated and after the injection of quinine into the duct no œdema ensues, however long the nerve be stimulated. I have fully confirmed these observations. The most probable interpretation of these facts, it seems to me, is that quinine prevents the passage of fluid through the glands by action on the gland cells, but does not prevent lymph transudation. That atropine, however, acts directly on the capillary wall, as well as upon the gland cell, in such fashion as to prevent lymph transudation and secretion.

A further indication that atropine checks lymph transudation is the diminution in thoracic lymph flow after its injection. Tschirwinsky[69] found that in morphinized animals thoracic lymph flow fell from 3.75 cc. to 1.5 cc. and from 10 cc. to 4.2 cc. in a given time. Atropine neutralized, also, the increased flow due to curare. In the latter case it fell from 9 and 10 cc. to 2.5 and 5.3 cc. in a given time. As there is reason to believe (Adami) that curare increases lymph transudation by direct action on the capillary wall, the inhibiting action of atropine may be referred to an opposite action on the same structure. Not knowing of Tschirwinsky's work, I had already performed similar experiments on the lymph flow, comparing it with pancreatic flow on vagus stimulation and after pilocarpine. I found (Experiment V that atropine temporarily neutralizes the large increase in lymph flow which occurs concomitant with increased panceas secretion during rythmic stimulation of the vago-sympathetic after division of the cervical cord, and also neutralizes the increased lymph flow due to pilocarpine.

Experiment Vb.

Medium-sized dog. Ether. Temporary pancreatic fistula. Tracheotomy. Cervical cord cut. Artificial respiration. Thoracic duct prepared. Lymphatics of head and neck ligatured. Readings every minute in cubic centimeters :

Thoracic Duct.	Pancreas.	Thoracic.	Pancreas.	Thoracic	Pancreas.
Vagi uncut.		.050	.009	.197	.009
.220	.02	.110	.013	.180	.004
.220	.02	.115	.012	.180	.008
.200	.02	½ hour interval.		.150	—
200	.015	.120	.013	.190	.006
.180	.015	.119	.012	Rt. Vagus. Ryth. Coil 9.	
.180	.010	.090	.009	200	.000
.190	015	.130	.011	.180	.000
.160	.013	.120	.010	.100	.002
.180	.017	.110	.010	**.300**	**.068**
.155	.017	.100	.008	—	.025
.155	.018	.100	.009	—	.015
.170	.015	.102	.004	—	.015
Cut vagi in neck.		.100	—	Off	
.280	.015	Clot.		.160	.020
220	.010	1 shock per second.		.140	.010
.160	.005	Rt. Vagus. Ryth. Coil 10.		.150	.005
100	.003	.150	.009	—	.010
120	.007	.220	.006	Rt. Vagus. Ryth. Coil 9.	
.100	.009	.250	.010	.360	.006
100	.010	.170	.005	.200	.009
060	.015	.230	.010	.240	.005
.050	.020	Current off.		Coil to 4.	
.090	.010	.200	.005	.200	.005
.120	.015	.190	.007	—	.008
.120	.003	.220	.007	Off.	
.120	.007	220	.005	Clot.	0.15
.065	.010	.310	.002	"	.011
.125	.010	.210	.001	Left Vagus. Ryth. Coil 9.	
.100	.011	.180	—	.550	.030

Thoracic.	Pancreas.	Thoracic.	Pancreas.	Thoracic.	Pancreas.
.290	.005	.120	.005	.270	.015
—	.005	—	.010	—	005
—	.005	.175	.025	.230	.005
—	.010	.225	.045	240	000
Coil to 6	.015	**.250**	**.055**	— suddenly	.120
—	**.060**	**.220**	**.110**	.250	080
—	**.090**	—	**.120**	Inject .5 cc. atropin into	
.240	**.100**	**.320**	**.140**	supra-scap. vein	
—	**.090**	**.300**	**130**	Stimulation continued	
Off Then on by accident		Off.		.250	.050
.230	.060	—	115	.200	070
Off.		.170	.065	—	.030
140	035	200	030	180	.020
.170	030	.150	—	.140	.015
.160	.030	.200	030	.145	.015
.120	.015	—	.020	.155	.015
.170	.015	—	.015	.110	.010
130	—	140	.015	.120	.015
.170	.010	.140	.010	Off.	
Left Vagus. Ryth.	Coil 6.	.145	.016	—	.007
.140	.007	.135	.009	.120	.008
.130	.002	.130	.005	.130	.010
.060	.009	.160	.017	.5 cc. atropin.	
.140	.090	Left Vagus.	Rythmical.	**.080**	.010
.200	.120	160	.002	**.040**	.010
—	**.130**	.250	.008	**.090**	.005
.290	**.140**	.210	.000	**.100**	.007
.235	**.110**	240	.001	**.100**	008
.280	**.130**	—	**.015**	**.120**	.012
.235	**.130**	**.300**	**.075**	.100	.007
.250	**.080**	**.300**	**.035**	.100	.005
Off.		**270**	**.045**	.110	.005
.340	**.154**	—	**.100**	—	006
.210	.116	**.350** .	**.100**	Stim. Left Vagus.	Coil 6.
.190	.052	**.300**	**.110**	.070	.010
.160	.043	—	**.140**	.100	.008
.190	.020	Left Vagus. Ryth.	Coil 6.	.120	—
.190	.020	**.220**	**.110**	.160	.002
.170	.025	**.280**	**.070**	160	.000
—	.011	Off.		.230	.000
—	.014	.200	.070	.200	.000
.155	.015	.200	.050	.260	.000
—	.010	.230	020	.170	.000
.150	.010	.180	.025	.200	.000
.150	—	.180	.030	Off.	
Left Vagus. Ryth.	Coil 6.	.155	.005	.250	000
.210	.010	.145	.005	.170	.000
.190	.000	Left Vagus. Ryth	Coil 6.	.190	.000

This experiment is of interest, not only as a clear confirmation of Pawlow and Mett, but because of the invariable increase in thoracic lymph flow occurring on stimulation of the vagus. I have repeatedly sought to obtain other experiments like it, but never with such success. The operation is long and apt to miscarry at some point.

Experiment XI.

Dog, etherized. Canula in thoracic duct. Readings in cc. every minute.

Thoracic duct.
.150, .220, .200, .180, .300, .230, .250.
1 cc. 1% pilocarpine into left femoral vein. Dog perfectly quiet.
.250, .300, 500, .600, .400, .460, .400.
1 cc. pilocarpine.
.490, .410.
1 cc. 1% atropine 1%.
240, **.090, .060, .070, .170, .110,** .120, .090, .090.
Moved head
.220.
1 cc. atropin.
.130, .100, .070, .060, .040, 120.
2 cc pilocarpine.
.100, .080, 120, .130.
1 hour interval.
.160.

It is not without interest in this connection that pilocarpine, contrary to atropine, increases lymph flow. This was first observed by Tschirwinsky.[60] My own experiments have yielded a positive result generally, but not invariably. In all cases the dogs had divided cervical cords, and generally divided vagi. They were all under artifical respiration. The lymph was measured in cc. for equal intervals of time.

Experiment	Before pilocarpine injection.	After the injection of 1–2 cgs. of pilocarpine.	Remarks
11	1.53	3.00	7 minutes. Dog motionless.
29	2.44	6.09	Some movements of abdomen.
14	0.50	1.72	Motionless. 9 minutes.
4	1.55	10.40	Movements.
62	1.41	1.69	No movements. Pancreas did not secrete either.

In experiments 11 and 14 there were no visible movements. The flow of the seven minutes after injection in No. 11 was double that of seven minutes before, and in experiment 14 was three times as great. In experiment 62, however, there was scarcely any difference.

The evidence presented in the foregoing pages, if not conclusive, certainly indicates that atropine restricts and pilocarpine increases lymph transudation. They may in this manner affect secretions. In any case, if the sympathetic causes its secretion by action on contractile tissue in the gland, there is no longer any reason against assuming that atropin acts directly on the gland cell, in such manner as to check the passage of fluid through it, and thus to prevent secretion.

d. THE ACTION OF QUININE AND NICOTINE.

We have considered the three main objections which have been raised against the chorda salivary secretion being an osmosis. There are, also, certain other phenomena which have been thought indicative of the independence of the secretory and dilator action of this nerve, and, hence, are worthy of a short criticism.

The first is the action of quinine, which when injected into the gland duct causes a temporary vaso-dilation, but no secretion. If, however, the chorda be stimulated, still greater dilation ensues and secretion takes place. This secretion is less than normal. Heidenhain[21] interprets this to mean that vaso-dilation cannot of itself produce a secretion, but that the secretory fibres must be aroused. (See literature reference No. 21, p. 85. Also reference No. 23, p. 45.)

The facts may, however, be otherwise understood. Quinine prevents the passage of liquid through the gland cell. This is shown by the fact that ultimately it prevents chorda secretion, even though the gland become œdematous. If the permeability of the gland membrane be thus diminished, the slight vaso-dilation caused by the drug may be insufficient to cause a secretion, whereas a larger vaso-dilation on stimulating the chorda might overcome this resistance. Another possibility is that the quinine reaches a portion only of the alveoli, poisons these, and throws their capillaries and arterioles into dilation.

On stimulating the chorda the secretion may be derived from unpoisoned alveoli of which the blood vessels have not hitherto been in dilation.

The value of Langley's and Heidenhain's observation, that the secretory fibres of the chorda tympani recover, after nicotine poisoning, before the dilator fibres, is seriously impaired by a defective method of determining whether vaso-dilation did, or did not, occur. If we admit that the rate of flow of blood from the gland's vein is a criterion by which we can determine whether vaso-dilation has or has not occurred their conclusion is justified. But reflection shows that if vaso-dilation be slight the amount of water passing out into the secretion might so reduce the bulk of blood flowing through the gland as to mask entirely all effects of the increased flow due to vaso-dilation. In fact, the flow of blood from the vein would be a safe criterion of dilation, only if there were no escape of liquid through the capillary wall, a condition which manifestly does not here exist. Langley's and Heidenhain's conclusion that the secretory function recovers before the dilator is, hence, unjustified. The same criticism applies, also, to Heidenhain's observation that after the chorda tympani has been cut and allowed to degenerate for three or four days stimulation still causes an increase in the paralytic secretion, but no increase in blood-flow from the vein.

c. EVIDENCE OF THE OSMOTIC CHARACTER OF THE SALIVARY SECRETIONS WHICH ARE ACCOMPANIED BY VASO-DILATION.

wish now to summarize briefly those features of secretions, accompanied by vaso-dilation, which indicate that they are of an osmotic character.

(1) In structure the salivary glands have all the requirements of an elaborate osmotic mechanism They are, essentially, extraordinarily thin-walled bags, possessing an enormous surface, containing a mass of hydroscopic indiffusible substances. The outer surface of this bag is in intimate association with a mesh work of capillaries so coördinated by the nervous system as to permit an almost instantaneous flooding of the gland mem-

brane. Plainly here are all the requisites of a delicate osmotic mechanism adapted to the most rapid osmosis.

(2) Chorda secretion is closely dependent on blood supply. (Compare p. 342.) Heidenhain has shown that partial occlusion of the artery diminishes the rate of secretion (p. 88, Breslau Studien IV.)

(3) If the osmotic equivalent of the blood be increased by the injection of strong salt solutions the secretion is diminished or altogether inhibited.[31 38]

(4) If the osmotic equivalent of the blood be decreased by the injection of water the rate of secretion is increased.[38]

(5) The rate of secretion is increased, other things equal, by an increase in the rate of blood flow through the gland.[38 23]

(6) The rate of secretion diminishes when the hylogens are washed out of the gland. (Paralytic secretions, secretion after long stimulation.)[23]

(7) Substances may be absorbed with extraordinary rapidity when injected into the duct (nicotine, atropine).

(8) If the percentage of salts in the blood be increased the percentage of salts in the saliva increases also. If the percentage of salts in the blood be decreased, the percentage of salts in the saliva decreases also.[38 31 11]

(9) If the artery of the gland be clamped for 20–30 minutes, and the blood thus completely cut off from the gland, on readmitting the blood a vaso-dilation ensues, so that the blood rushes red from the gland veins, and this vaso-dilation is accompanied by a spontaneous secretion. Stimulation of the chorda in no way alters this secretion during the first minute, nor until the dilation has somewhat diminished. This spontaneous secretion is a close duplicate of that observed by Levy in the secretion of sweat. [Experiment V (a).]

Although this spontaneous secretion might, perhaps, be explained by supposing that a direct stimulation of nerve-end or cell by the oxygen has taken place, it seems more probable to me to class it with the spontaneous secretion of sweat in the horse, following section of the cervical sympathetic, and to refer it to the direct effect of vaso-dilation.

f. CONCLUSION. THE PHYSIOLOGY OF SALIVARY SECRETION.

If the sympathetic salivary secretion shall be found to be due to the action of contractile tissue, and if the criticisms of the objections to considering the salivary secretion, coincident with vascular dilation, an osmosis, be sustained by subsequent work, the following conclusions concerning the physiology of this secretion may be drawn.

The salivary glands may be caused to secrete, either by the action of contractile tissue under control of the sympathetic nerve or by osmosis under control of the vaso-dilator nerve. Probably in normal secretion both of these nerves come into play, but of this evidence is as yet lacking.

Drugs, or other reagents, may arouse secretion by action on either or both of these mechanisms. I would suggest that secretion following strychnine injection, camphor, pikrotoxin, physostigmin (after division of the chorda) are due to the contractions of the contractile tissue. All of these drugs stimulate the nerve centers and cause a pronounced vaso-constriction. On the other hand, pilocarpine, nicotine, muscarine, curare and chloral hydrate, or other drugs with a similar action on the vascular system, probably cause secretion partly by vaso-dilation and partly by increasing the permeability of the gland membranes. Such drugs work through an osmotic mechanism. A third class of drugs, such as quinine, atropine, hydrochloric acid or sodium carbonate may produce vaso-dilation, but probably act, also, on the gland cells in such manner as to diminish their permeability. Most of the work which has hitherto been done upon the action of drugs on salivary secretion needs to be repeated with the possibility in mind that the chorda and sympathetic induce secretion in these different ways.

The osmotic mechanism of secretion in the salivary glands is probably dependent on the condition of the gland and capillary membranes, upon the composition of the blood, upon the rate of flow of the blood and the character and amount of hylogens present within the gland. The evidence that the course of osmosis is controlled by the action of nerves directly on the gland cells is open to serious criticism. That chorda salivary secretion can ensue without vaso-dilation may be seriously doubted, not only for the reasons already stated, but because in the pancreas there is good reason to believe that secretion can not take place without vaso-dilation. (See p. 361.)

V. SOME OTHER SECRETIONS.

The submaxillary gland, considered in the foregoing pages, may be taken as a type of all the salivary glands, as each possesses a dilator secretory nerve, and a constrictor, sympathetic secretory nerve. I wish now to consider some other secretion in the light of the conclusions derived from the physiology of the submaxillary.

a. THE PHYSIOLOGY OF SWEAT SECRETION.

There is reason to believe that the mammalian sweat glands also have a double mechanism of secretion, a muscular and an osmotic. These glands are surrounded by a sheath of muscle fibres lying, like those of the skin glands of amphibia, between the cells and the basement membrane. From the observations of Ranvier, Joseph and others, who have shown that upon stimulation of the sciatic this muscle contracts, there can be little doubt that a secretion may thus be formed. Probably sweat secretions ensuing coincident with vaso-constriction, upon the injection of strychnine, upon stimulation of the sciatic in the amputated limb or after compression of the blood vessels is due to this mechanism.

On the other hand, certain secretions of sweat are too copious to be due to muscular constriction of the gland. That those secretions probably fall under the second, or osmotic, mechanism is shown by the following facts:

(1) The coincidence of vaso-dilation and sweat secretion. Most sweat secretions are normally accompanied by vaso-dilation. If the cervical sympathetic of the horse be severed, strong hyperæmia and sweating occurs on the side of the neck the nerve governs. This sweating ensuing after nerve division

can hardly be explained, I think, on the basis of secretory cell activity.

(2) Pilocarpine, which does not cause contraction of the muscular sheath, causes a profuse secretion.

(3) The vaso-motor and secretory fibres in the cat follow the same paths.

(4) Pilocarpine causes sweat secretions fourteen days after nerve degeneration.

(5) If the blood supply be cut off, on readmitting the blood after 30 minutes, a spontaneous secretion occurrs.[41] The similar secretion in the submaxillary is invariably accompanied by vaso-dilation.

(6) Increasing the capillary blood pressure or drinking large quantities of water increases secretion.

The facts, as far as they go, are the same as those observed in the cerebral salivary secretions and pancreatic secretion They justify us, I believe, in classing all three secretions in the same category. That these sweat secretions are of an osmotic character would thus be indicated. That other sweat secretions are due to muscle there can be little doubt.

b. THE SECRETION OF THE PANCREAS.

Secretion of the pancreas is normally accompanied by vaso-dilation. In its relation to atropine, its increased content of organic bodies coincident with an increased rate of flow, and in taking place after compression of the aorta, pancreatic secretion resembles the submaxillary secretion on stimulation of the chorda tympani. There is reason to believe, however, that the pancreas cannot secrete unless the blood vessels dilate. Thus the means employed by Pawlow,[57] Mett[53] and Kudrewetsky[32] to give the vagi a secretory function are just the means used by Bowditch, Luchsinger and others[56] to give the sciatic and other mixed dilator and constrictor nerves a dilator action. These authors either cut the vagi and splanchnics, and allowed them to degenerate three or four days, or else they stimulated them with rythmic induction shocks, at the rate of one per second after division of the cervical cord. There are two possible explanations of the fact that stimulation of the normal nerve with the cord undivided causes no secretion. Either the nerve carries inhibitory secretory as well as secretory fibres, or stimulation of the nerve is unable to cause a secretion without vaso-dilation. The first alternative Heidenhain has particularly combatted in the case of the submaxillary, and it appears to me lacking all proper experimental basis. The second alternative is probably the true explanation, for the reason that stimulation of the *normal* nerve below the cardiac branches causes no alteration in blood pressure, and for the reason that the treatment to which the nerve is subjected is calculated to give it a dilator action. If this be true the pancreas would appear fundamentally different from the salivary glands, unless, as I have endeavored to show, the latter are, also, in reality, unable to secrete on stimulation of the chorda or other cerebral nerve, unless vaso-dilation ensues.

Further evidence of the dependence of pancreatic secretion on vaso-dilation is furnished by the action of pilocarpine, chloral hydrate[19] and curare, drugs which cause vaso-dilation and secretion, and by strychnine,[19] or digitalis, drugs which cause vaso-constriction and inhibit secretion. Heidenhain,[23] also, has observed a close correspondence between vaso-dilation and secretion, and between vaso-constriction and the cessation of secretion. This parallelism between vaso-dilation and secretion can not be accidental. It indicates, I believe, that the dilation is the cause of the secretion, other things being normal.

VI. GENERAL CONCLUSION.

We have now considered the evidences of the existence of secretory nerves, and the reasons for believing that secretion is a function of the gland cells. While readily admitting the possibilities that secretion may in certain instances be a function of the gland cell, controlled by the action on it of secretory nerve fibres, we have seen reason to believe that certainly many so-called secretions are due not to the gland cell, but to the action of contractile tissue either within or about the gland. Among such secretions are the salivary secretions following stimulation of the sympathetic, certain secretions of sweat, the secretion of the cephalopod salivary glands and of the skin glands of amphibia.

Whether those secretions which are normally accompanied by vaso-dilation, such, for instance, as the salivary secretions following stimulation of the cerebral nerves and the secretions of the alimentary tract and its appendages, are governed by nerves acting directly on the gland cells, or indirectly through the vascular system, cannot with certainty be said. But I believe it has been shown in the present paper that the evidence which has hitherto been offered that such secretions are controlled by nerve action on the gland cell is open to serious criticism. The remarkable parallelism between the hypothetical secretory and vaso-dilator fibres, the close dependence of such secretions on the vascular system, the general features of such secretions and the structure of glands, all indicate, I believe, that osmosis is the essential cause of these secretions, and that they are controlled by the action of nerves on the vascular system. No one would deny that the course of these secretions is modified by the condition of the gland or capillary wall, and that that condition is easily affected by drugs, but that nerve action directly affects that condition, I do not believe the evidence entitles us to say.

Probably the study of these secretions from the standpoint of osmosis will bring to light facts difficult to reconcile with our present knowledge of.osmosis. But while our knowledge of the latter process through membranes undergoing chemical change, such as gland membranes, remains in its present fragmentary state, I do not believe that we are justified in assuming a special sort of secretory activity on the part of the gland, or capillary cell, unless the facts are certainly irreconcilable with any other hypothesis.

In short, while fully admitting the possibility that nerves may act on gland cells, in some way affecting osmosis through them, it appears to me that, in the present state of our knowledge of secretion, the assumption of a particular secretory function of cells, and of special secretory nerves, is unwarranted, unnecessary, and, in certain particular cases, opposed to the phenomena of the secretion itself.

SUMMARY OF RESULTS.

(1) The sympathetic nerve induces salivary secretion by acting on contractile tissue in the glands and thus causing a compression of ducts and alveoli.

(2) The chorda tympani, or other dilator salivary, secretory nerve probably causes secretion by its dilator action on the blood vessels, thus increasing osmosis.

(3) The evidence that the chorda tympani acts on the gland cells is open to serious objections, as follows :

(*a*) Atropine probably acts directly on the gland cells and capillary endothelium, diminishing their permeability.

(*b*) The post-mortem chorda salivary secretion is possibly due to a back flow of blood from the veins owing to a dilation of the capillaries.

(*c*) The increased content of organic matter in a secretion coincident with an increased rate of secretion is of little value as evidence of secretory nerves, because (1) saliva is generally not a true solution, and (2) a weak stimulus probably arouses but a portion of the gland.

(*d*) The evidence derived from the action of nicotine and the degenerated chorda tympani that secretion may ensue on stimulation of the chorda without vaso-dilation is of doubtful value, because of an erroneous method of determining that vaso-dilation had not occurred.

(4) The sweat glands and the amphibian skin glands, like the salivary glands, receive a double nerve supply and probably possess a double mechanism of secretion, *i. e.*, a muscular and an osmotic.

(5) Whether secretory nerves exist or whether secretion is ever a function of the gland cell must be considered at present an open question.

(6) The thoracic lymph flow in dogs reacts to nerve stimula-

tion and drugs very similar to pancreatic secretion. It is increased by rhythmical stimulation of the vagi after division of the cervical cord and by pilocarpine and chloral hydrate, and decreased by atropine.

COLUMBIA UNIVERSITY, April, 1898

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SOME PASSAMAQUODDY DOCUMENTS.

J. DYNELEY PRINCE.

(Read April 25, 1898.)

THE Passamaquoddy Indians of Maine are members of the *Wabanaki* or northeastern group of the great Algonkin family which in earlier times occupied territory extending from James' Bay on the north to the Carolinas on the south. The *Wabanaki* tribes which still exist are (1) the St. Francis Indians, of Canada, who are at present a small sept of mixed race resident on the St. Francis river, near Quebec. These people, who call themselves by the generic name *Abnaki* or *Wabanaki*,[1] are composed of *Wabanakis* of various tribes from New Hampshire and Massachusetts, of Sagadahoks, and of Norridgewoks,[2] from Maine. (2) The Penobscot Indians of Maine are very closely allied both in race and language to the St. Francis tribe. (3) The Passamaquoddies[3] of Maine are practically identical with (4) the Maliseets (Milicetes) of New Brunswick. (5) Finally, the Micmacs of Nova Scotia and New Brunswick constitute the easternmost branch of the *Wabanaki*.

The Passamaquoddies, like many other Indian tribes, have an extensive oral literature, consisting of historical, mythological and legal traditions, as well as many songs and recitations. A great part of this material is preserved by means of a mnemonic system of wampum shells arranged on strings in such a manner as to suggest to the mind of the reciter certain sentences of a tale already committed to memory.[4]

In 1887, during a visit to Bar Harbor, Me., I obtained from Mr. Louis Mitchell, a Passamaquoddy Indian, who was at that time Indian member of the Maine Legislature, some selections from this oral material which he had committed to writing. Undoubtedly, the most important of these, both from an historical and ethnological point of view, are the so-called Wampum Records, which embody a detailed description of various ancient rites and ceremonies, peculiar not only to the Passamaquoddies, but to all the northern Algonkin clans (*Wabanaki*), who, after a long period of internal strife, seem to have formed a close offensive and defensive alliance. These records I have published in the *Proceedings of the American Philosophical Society*, XXXVI, pp. 479–495. Besides the Wampum Records, I have a number of other documents, the most important of which is an outline of the *Wabanaki* history previous to the establishment of the inter-tribal treaty of peace between the *Wabanaki* clans and the foundation of the common *modus vivendi* set forth in the Wampum Laws.

I have ventured in the following pages to reproduce this historical sketch, which has, at least, the merit of being purely native, and, as a specimen of the Passamaquoddy poetic genius, I have added, in both Indian and English, part of a characteristic love-song.

The original text of the Indian history was not included in the manuscript which I received. It is necessary to remark that, as Mr. Mitchell's translations were written in what may be termed Indian-English, I have been compelled to rearrange his versions into our current vernacular. His Indian text, both in the song in the present paper and throughout the Wampum Records, is written syllabically without any attempt to divide the sentence into words, so that it is extremely difficult to edit the Passamaquoddy original with even approximate correctness.

WABANAKI HISTORY PREVIOUS TO THE ESTABLISHMENT OF THE WAMPUM LAWS.

In former days the *Wabanaki* nation, the Indians called *Meguyik*[5] or Mohawks and other members of the Iroquoian Six Nations[6] were want to wage bloody and unceasing war with one another. The *Wabanaki* nation consisted of five tribes, *e. g.*, Passamaquoddies, Penobscots,[7] Micmacs, Maliseets[8] and the tribe (now extinct) which formerly inhabited the banks of the Kennebec river.[9] The bitterest foes of the *Wabanaki* were undoubtedly the *Meguyiks* or Mohawks, who, on the slightest provocation, would send bands to harry them and destroy their crops. The Mohawks invariably treated their prisoners with the most merciless severity, showing no pity even to the women and children. A favorite torture which they frequently practiced was to build a large fire of hemlock coals, into the flames of which they drove their captives, compelling them to walk back and forth over the glowing coals until relieved by death. No case is on record where a brave of the *Wabanaki* nation succumbed to the pain. Their warriors would always pace the fiery path with undaunted resolution and without uttering a sound until nature put an end to their agony. Tortures of this sort were practiced by all the tribes, but the Mohawks exceeded the others in cruelty.[10]

The cause of the strife was an hereditary dispute about hunting grounds. Besides the enmity which they nourished in common against the Six Nations, the *Wabanaki* had also internal disputes. Thus, the Penobscots were at feud with the Maliseets and the Micmacs with the Passamaquoddies.

The first war between the last mentioned tribes was brought about by the quarrel of two boys, sons of chiefs. On this occasion the Passamaquoddies were on a friendly visit to the Micmacs, during which the sons of the Passamaquoddy and Micmac chiefs went shooting together. They both shot at a white sable, killing the animal by their joint effort, but each lad claimed it as his game. Finally, the Passamaquoddy boy, becoming enraged, killed the son of the Micmac chief. The latter on hearing of the murder could think only of vengeance and positively refused to listen to the Passamaquoddy chief's attempt at conciliation. The latter even offered the life of his own son who had been guilty of the murder, but all to no purpose. In consequence of this unfortunate occurrence the celebrated "great war" was then declared which lasted many years.

The Micmacs, although more numerous than their enemies, were inferior warriors, so that the victory was always (*sic*) won by the Passamaquoddies. So great was the hostile spirit that the two tribes fought whenever they met, paying no heed to the time of year. On one occasion, the Passamaquoddies went to *Tlancowatik*, thirty miles west of St. John, N. B., with a small party consisting principally of women and children with the chief and a few braves. At this place they met a number of Micmacs on their way to Passamaquoddy Bay. The Micmac chief being a lover of fair play ordered his men to land on an island to await the coming of a messenger. The other chief sent word that on the following day "the boys would come out to play." As the Passamaquoddy chief had very few men able to bear arms, he made the women attire themselves like warriors, so that from a distance they might be mistaken for men and directed them to play on the beach shouting and laughing as if entirely fearless. The Micmac chief, deceived by this stratagem and being afraid, summoned his braves to council and setting forth the disasters which had been caused by the long war advised a treaty of peace. This proposition was made to the Passamaquoddies who, wearied by the perpetual state of unrest, gladly acceded to the request. A general council was accordingly called, by which it was decided that "as long as the sun rises and sets, as long as the great lakes send their waters to the sea, so long should peace reign over the two tribes."

The usual ceremonies for making peace were then observed, as follows: (1) a marriage was contracted between a brave of the challenging people and a maiden of the challenged people. This was regarded as a type of perpetual future good will. (2) A feast lasting two months was celebrated nightly and (3) games of ball, canoe and foot races and other sports were carried on. After such ceremonies were over no breach of a treaty is on record, not even a single murder.

After the great Micmac war was ended, the Passamaquoddies lived at peace except for occasional raids of Mohawks, but the latter finally received a blow from which they never recovered, the details of which are as follows: It was the custom of the Mohawks to make night attacks and at one time, when the Passamaquoddies were at the head of Passamaquoddy Bay,[11] the Mohawks approached the camp, which was called Quenasquamcook,[12] with the purpose of utterly destroying it. On this occasion, however, they were seen by a Passamaquoddy brave whose people lay in ambush for them. It was the custom of chiefs to wear medallions of white wampum shells which were visible at a long distance, particularly in the moonlight. Picking out in this way the person of the Mohawk chief whose name was *Lox*, "panther," [13] the watching braves shot him first, owing to which calamity the Mohawks were thrown into confusion and fled. The Passamaquoddies followed them as soon as day broke, but the tracks were so scattered that they could not find the refugees. It was ascertained afterwards that the Mohawks had quarreled among themselves, one party being in favor of making peace with the enemy, while another faction was strongly opposed to such a measure. The discussion of the question ended in a fierce combat. This was the final blow to the Mohawk cause, so that the nation ever afterward sought to be at peace with the Passamaquoddies.

After this battle the Passamaquoddies were never again molested, but the Penobscot tribe was still at war with the Maliseets and Mohawks and, in fact, were nearly destroyed three times by their ruthless foes. A most interesting legend of this Mohawk war is the account of the miraculous revelation to the Penobscots by *Wenagameswook* or fairies of the approach of a large body of Mohawks. Two Penobscots were coming down the Penobscot river from their winter hunting, when they spied a newly made canoe paddled by what seemed to be two small boys who, pursue as they would, always kept at an even distance ahead of them. Finally, the supposed children stopped and called out to the wondering Indians "*Nowut Kemaganek Meguyik*" "At *Nowut Kemaganek* there are Mohawks." As the hunters had noticed some chips floating down the stream, they believed the report at once. The Mohawks had been making rafts with which to float down the river in order to destroy the Penobscot tribe. As soon as the hunters reached Oldtown they told their curious tale, which was immediately credited by the old men, who straightway prepared for war. The fairies, according to their belief, always either appeared in person or carved a warning on rocks before a danger which threatened the tribe. Greatly excited, the Penobscots despatched scouts in all directions, so that when the Mohawks arrived, they found the warriors perfectly prepared awaiting them behind a brush-wood breast-work (*lisignigen*).

No damage was done at that time, but on another occasion the Mohawks completely defeated the Penobscots, saving only one man as a guide to the St. John's river (*Wulastuk*).[11] Constructing rafts there, they aimed to float down strean for the purpose of destroying the village of Maliseets (*W'ulastukuk*). The Penobscot guide told them that there was no falls or rapids before them, knowing full well all the time that on this river is the great fall of Chikchenikbik of nearly 100 feet, the roar of whose torrent is perfectly inaudible to the traveler until he is within a few yards of it. The Mohawks, trusting to their guide, were all sleeping on their rafts, when the Penobscot, suddenly jumping overboard, swam ashore and left his 600 sleeping foes to be carried over the falls. Not a man escaped to tell the tale except the Penobscot guide.

The Mohawks, discouraged by their repeated failures, decided to make a treaty of peace among all the nations, apportioning the disputed hunting grounds as follows: To the Penobscots, the Penobscot river and its tributaries; to the Maliseets the St. John's river and its tributaries; to the Passamaquoddies, the St. Croix river[15] and its territory, and to the Micmacs their own streams. The *Wabanaki* lived ever after as one nation, undisturbed by internal strife and keeping the Mohawks and Six Nations at peace with them by presenting a united front. This is the origin of the Wampum Laws which were the product of the union of the tribes.

The following song is the plaint of the youthful Indian lover who sings to his fair one before going away to his winter hunting in the autumn when the leaves are *red*. He promises to return to her embraces in the Spring when the *green* foliage has begun to bud. The song has in the original four sense-stanzas. A refrain precedes the first, second and fourth and is repeated for the last time after the fourth verse. In Mitchell's MS. no translation is given of the fourth stanza, so that I have omitted it and the final refrain in the present paper.

Passamaquoddy Love Song.

Refrain.	
Anigowanotenoo ! *Boski k'tlabin elmi nelemwik elmi papkeyik ; boski k'tlabin, Anigowanotenoo !*	Anigowanotenoo ! Oft on a lonely day thou look'st on the beautiful river and down the shining stream. Oft thou lookest, Anigowanotenoo !
1. Neket m'pesel etli-nemiot-yikw. Etuchi w'linakw-ben sebayi sibook ; etuchi w'li baquasketen. K'machtena nolithasiben ; mechinoltena keppitham'l, Anigowanotenoo !	When last I saw thee, how beautiful that fair stream looked, how lovely was the silver moon. Thou knowest how happy we were. Ah, since that night I think of thee always, Anigowanotenoo !
Refrain.	
Boski k'tlabin elmi nelemwik naga elmi papkeyik Anigowanotenoo.	Of't on a lonely day thou look'st on the beautiful river and down the shining stream, Anigowanotenoo ?
2. Negetlo he eli-alnisookmekwben sebayi guspenik etuchi welanakw-sititben wuchowek he elimachip klamisken mipisel, Anigowanotenoo !	When we paddled the canoe together on that beautiful lake how fair the mountains looked and how we watched the red leaves whirl in the gentle breeze, Anigowanotenoo !
3. Anigowanotenoo, nittloch apch eli-alnisooknukw tan etuch apachyaie ; tanetch etuch boski p'kesik mipisel yut pemden nit k'tlaskooyin.	Anigowanotenoo, we will go once more in a canoe and watch the beautiful green leaves on the mountain.
Refrain.	
Boski k'tlabin elmi nelemwik elmi papkeyik, Anigowanotenoo.	Of't on a lonely day thou lookest on the beautiful river and down the shining stream, Anigowanotenoo !

EXPLANATORY NOTES.

[1] *Wabanaki* means "inhabitants of the East or dawn country" from *waban* "daybreak" and *aki* "land, territory." The latter is a suffix used in composition for "land, region" (see Brinton, The Lenape and their Legends, p. 191).

[2] Norridgewock or Norridgewalk is on the Kennebec and not as Gatschet states on the middle Penobscot (*Nat. Geogr. Mag.*, VIII, p. 23). Its original name was *Nanrantsouack*, which may have meant "stretch of still water," although this is not certain. The settlement was the home of the nucleus of the present St. Francis clan, where Father Rasle, the author of the Abnaki dictionary, first established himself in 1689 (see Pickering's edition of Rasle's work in *Amer. Acad. Sci. and Arts Mem.*, New series, 1833, Vol. I, p. 372). The tradition of the present Abnakis of Canada asserts that their ancestors came from Maine and New Hampshire.

[3] The Indian form of the name Passamaquoddy is *Peskatumagatiek* "those belonging to the place abounding in pollock-fish" (*peskatum*); cf. Gatschet, *l. c.*, p. 23.

[4] See Prince, *Proc. Amer. Philos. Soc.*, XXXI, p. 480.

[5] The real Mohawks called themselves *Caniengas*. When first known they were living on the south side of the Mohawk river between Canajoharie and Schoharie creeks in New York Province. Being loyalists, they removed to Canada with Brant at the time of the American Revolution (Hale, the Iroquois Book of Rites, p. 34). It is probable that Mitchell means here by Mohawks (*Meguyik*) not only the *Caniengas*, but also the Canadian Iroquois. The whole Iroquois race is called in the St. Francis language *Magua*, and indeed the term Mohawk which is a corruption of the word *Magua* was used in England in much the same way.

[6] Originally Five Nations, *e. g.*, Onondagas, Mohawks, Oneidas, Senecas and Cayugas who called themselves in the Iroquoian dialect *Hotinonsionni* (Prince, *l. c.*, p. 438). The Tuscaroras came into the league later. The Iroquoian name for the completed federation was *Kanonsionni* "the league of the united households" (Hale, *l. c.*, pp. 10, 171).

[7] The original form of the name Penobscot is *Panawampskik* (St. Francis *Panapskak*) "where the steep rocks are."

[8] The Maliseets (Milicetes) who speak practically the same language as the Passamaquoddies are called Etchemins by the Micmacs.

[9] Undoubtedly the Norridgewoks mentioned notes. Kenebec is probably a slight alteration of *Kinebek* "deep river."

[10] In connection with this undoubtedly biassed statement, cf. Hale, *l. c.*, p. 83, ff. on the Iroquois character. There is no reason to believe that the members of this much-maligned race were any more barbarous in the treatment of their captives than their hereditary Algonkin foes.

[11] See note 3 and Gatschet, *l. c.*

[12] *Quenasquamcook* "at the gravel beach of the pointed end" (cf. Gatschet, *l. c.*, p. 22).

[13] Delaware, *quenischquney*, literally "long tailed" (Brinton, Lenape Eng. Dictionary, p. 121). Ojibwa *peshew;* Micmac *utkogwech.*

[14] *Wulastuk* "the good river"=Aroostook, *e. g.*, the St. John river. *Wulastukuk* is a locality "at or near the St. John river." The Micmacs call St. John *Menawges* "the place where dead seals are collected."

[15] Called *Skutik* in Passamaquoddy (according to Mitchell) from *squt* "fire;" "at the fire," owing to the custom of spearing salmon by torchlight. It is much more likely that the name is an allusion to the burnt lands or clearings on the banks of the river or on Schoodic lake. Tradition asserts that large forest fires took place here about 1675.

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THE PHYLOGENETIC SIGNIFICANCE OF CERTAIN PROTOZOAN NUCLEI.

GARY N. CALKINS.

(Read April 11, 1898.)

[PLATE XXXV.]

THE nucleus is often looked upon as a more or less well-defined morphological element of the cell, possessing in its various phases a common type of structure and composed in all cases of similar substances. A comparison of cells in various tissues whether vertebrate or invertebrate, plant or animal, shows that in the majority of cases the nuclei are so similar that, with slight variations, a description of one answers for a description of all. In resting phases the similarity is shown in the distribution of chromatin, linin, and in the nucleoli, while the nuclear membrane is usually present. In active phases metazoan nuclei as a rule, pass through the same stages of spirem-formation, loss of membrane, chromosome-formation, and various processes of re-formation. The differences between such nuclei being confined mainly to variations in number of chromosomes, in arrangement in the nuclear plate, and in the mode of division.

The nuclear type being so constant in higher animals we must look to the lower animals—that is, to the Protozoa—to find not only the prototype, but any transitional forms leading up to the highest types, bearing in mind, however, that notwithstanding the constancy of type manifested in the nuclear forms and mitotic processes of the latter, individual differences may have arisen and mitotic processes may have developed in quite diverse ways. In the present paper it is my object to bring together a few facts, some of which are new, showing how in the Protozoa, the nucleus of the type found in Metazoa may have arisen from simpler forms, and how in its mitotic phenomena it passes through stages represented by permanent nuclei of lower Protozoa.

In the first comparison of metazoan with protozoan nuclei we are at once beset with difficulties. Protozoan nuclei vary so widely among themselves that, save for the same class of organisms, a description of one nucleus would not correspond at all to that of another. Some resemble the ordinary type of nucleus in the Metazoa, others are so different from this type that they can scarcely be compared. In general the nuclei of the Protozoa are much simpler in structure than those of Metazoa. Chromatin is present in all cases but other parts which are usually found in nuclei of the Metazoa are frequently missing, *e. g.* the linin, the nuclear membrane or the nucleolus. On the other hand, bodies are occasionally found within the nucleus of Protozoa which are absent altogether or present in some other form, in Metazoa ; such for example are the significant centrosome-like bodies found in *Euglena* and allied forms.

There are so many different types of nuclei in the various classes and orders of the Protozoa that it should be possible to select a chain of forms connecting the simplest known type with the highest. Such a sequence may be sought for in the structure of the resting nucleus or in the method of division. An ideal sequence would result if the two lines could be developed simultaneously, but this is extremely difficult as a nucleus may be high in the series of nuclear structures and low in the matter of mitotic division. The nuclei of *Actinosphærium*, *Actinophrys* and *Noctiluca* offer a striking example of this fact, the two former resembling the structure of the metazoan type more closely than the latter, while in mitosis the latter is much nearer the metazoan type than are the former. In questions of phylogeny however, morphological characters are usually of more importance than physiological characters and this must be kept in mind in the present discussion. A number of authors have built up theories of phylogeny on the method by which the nuclei of Protozoa divide, and the obvious result is a series of mitoses which satisfy to a certain extent the requirements in such a scale, but the series applies only to the nuclei during division while the nuclei at rest are quite different, and the cell-bodies to which the nuclei belong, often represent widely separate classes of animals. A phylogeny based upon such a foundation must necessarily be weak, for it is perfectly possible that various classes of Protozoa may develop mitotic modifications quite independently of each other and yet along the same lines.

In view of the fact that the nuclei of the Protozoa show such wide differences it is not surprising that some forms should possess no structures which can be accurately defined as nuclei. Indeed, if the nucleus be regarded merely from a morphological standpoint it is quite easy to conceive of cells which possess no nuclei (Haeckel's Monera, in part) and to imagine groups of cells intermediate between such forms and those in which a definite morphological nucleus can be made out. These intermediate forms are the subject of the present paper.

The observations were made on various Protozoa including simple flagellates, dinoflagellates, rhizopods, heliozoa, ciliates, suctoria and *Noctiluca*. The material was fixed with sublimate acetic (5 per cent. acetic), picro acetic, Hermann's fluid, and saturated sublimate. The stains used were mainly iron hæmatoxylin with orange or Congo red, and the Flemming triple. The nuclei were studied from thin sections or from total preparations, sections giving the best results.

THE SO-CALLED "DISTRIBUTED NUCLEUS."

A number of forms which Haeckel included in his enucleate Protista, have subsequently, by the use of better optical instruments and improved technique, been found to contain minute particles of chromatin which are distributed without definite order throughout the cell. Such types have been called distributed nuclei. Occasional instances of this type of nucleus have been found in nearly every group of Protozoa. In the Ciliata, Gruber ('84) found that *Chænia teres* and *Trachelocerca phœnicopterus* possess no true nuclei but minute granules of chromatin distributed throughout the cell-substance. These granules, according to Gruber, unite into a common body previous to division and are then halved.

The Ciliata are highly specialized Protozoa and it is probable that, among them, the primitive distributed nucleus is very uncommon; we should expect to find this condition in the simpler and less differentiated forms like the flagellates or the lowest plants. In the latter, especially the bacteria and the closely allied Cyanophyceæ, Bütschli ('90 and '96), confirmed by Zacharias ('90), described cells possessing a distinct protoplasmic structure enclosing numerous granules which he found to be chromatin. Bütschli regards these cells as nuclei with only a fine layer of protoplasm around the outside. The chromatin is laid down on what appears to be the cytoplasmic reticulum but which according to his view, would be linin. However this view may be in regard to the bacteria it cannot hold for cases of distributed nuclei among the Protozoa.

A flagellate belonging to the genus *Tetramitus* possesses a nucleus of the same distributed type. The protoplasmic structure of this flagellate is strikingly similar to Bütschli's figures and photographs of *Chromatium* and other bacteria. The periphery is characterized by a distinct alveolar layer consisting of vacuoles of regular size and arrangement, and the walls which bound them. The central portion is made up of alveoli of various sizes and is much looser in texture than the outer layer (Plate XXXV, Figs. 1–4). After fixation with Hermann's fluid and staining with Flemming's triple stain, this cytoplasmic structure appears yellowish or of an orange tone. In the endoplasm the substance of the alveoli appears to have run together at one point to form a more compact, denser aggregate which, with the stain used, appears homogeneous (Fig. 1 *A*). With the iron-hæmatoxylin the fused portion becomes more conspicuous although not more deeply stained than the cytoplasmic reticulum. It appears to be a coalescence of cytoplasmic microsomes. No inner structure could be made out, although in some cases a lighter area (Fig. 2) was faintly indicated in the center. In some individuals the body in question appears biscuit-shaped as though undergoing division (Fig. 4).

In addition to the above structure the cells of *Tetramitus* contain a number of comparatively large-sized granules which stain intensely with saffranin in the Flemming stain and black with the iron-hæmatoxylin. In division they are separated into two equal groups in the daughter-cells (Fig. 5). From the relation to stains and the general appearance during rest and division I have no hesitation whatever in comparing them with the granules of chromatin described by Bütschli in the case of *Chromatium* and *Bacterium termo*. The most frequent position of the granules is at the extremity of the cell opposite the flagella, where they form an aggregate of greater or less density, but in which the individual granules can be distinctly made out (Figs. 2, 4). There is reason to suppose that this close aggregation indicates the approach of division, for the culture was extremely active and the monads were increasing rapidly. Many individuals were found, however, in which the chromatin granules were distributed over all parts of the cell (Fig. 1). Aggregates were also found in the flagella-end of the cell (Fig. 3), although such cases were comparatively rare. In this connection it is a significant fact that division of the body begins at that end of the animal which holds the chromatin, in this case at the posterior end, although the majority of flagellates begin to divide at the flagellate end (Fig. 5).

This type of nucleus must be very primitive. It has no membrane and no linin unless the meshes of cytoplasm around the chromatin granules be called linin. Is there a nucleolus? Were it intra-nuclear the cytoplasmic body described above might be called a nucleolus on account of its staining reactions, but it is not intra-nuclear, and furthermore it appears to have a special function in the activity of the cell. Wherever the aggregate of chromatin granules may be found the cytoplasmic body is invariably in the near vicinity. It appears to divide before the group of chromatin is halved, and in the daughter-cells of a just-divided form the chromatin granules appear to surround the cytoplasmic body (Fig. 5.) It is certainly conceivable and in view of the phenomena in other allied Protozoa, almost probable that this cytoplasmic body exerts some influence upon the chromatin granules to attract them about itself at certain stages.

THE INTERMEDIATE TYPE OF NUCLEUS.

The "intermediate type" includes those nuclei which have either a faint nuclear membrane or none at all, and which persist in the form of spherical aggregates of chromatin granules about a central attractive body. The majority of the common autoflagellates possess nuclei of this type and a description of a few will suffice for all. The forms selected are *Microglena*, *Synura*, *Chilomonas*, *Trachelomonas* and *Euglena*.

Microglena punctifera (Pl. XXXV, Fig. 6). This minute form possesses two large chromatophores which occupy the greater part of the cell and which obscure the finer protoplasmic structure. There is a single flagellum attached at the end where the chromatophores come together. At this end also a small pigmented "eye-spot" can be made out (Fig. 6, E). The nucleus lies between the chromatophores in the center of the cell. It consists of a large number of chromatin granules surrounding a deeply-staining central body. The granules are loosely arranged, often forming an irregular outline and apparently are not bounded by a nuclear membrane.

Synura uvella (Pl. XXXV, Fig. 7). This beautiful colony-form is similar to *Microglena* in regard to nuclear structure, and, being larger, the details can be more readily made out. The monads are attached at a central point by their sharp ends, which form the lower extremity of the gelatinous mantle surrounding the protoplasmic body. The two equal-sized flagella arise from the outer end of the protoplasmic body and run nearly parallel through the outer mantle. Two large chromatophores occupy the greater part of the cell, each being curved like the half of an empty nut shell. The nucleus is enclosed in the space between the chromatophores. It is excentric in position, lying nearer the flagella end. Like the nucleus of *Microglena* it is made up of fine granules of chromatin disposed around a distinct central body. Here also the chromatin appears to be free from a bounding membrane, but in both of these forms the nuclei are distinctly outlined and well marked off from the surrounding cytoplasm while they invariably appear round in section.

Chilomonas cylindrica Ehg. (Plate XXXV, Figs. 8, 9, 10.) This very common flagellate is characterized by the buccal depression typical of the family Cryptomonidæ, by two equal flagella, by an œsophagus-tract in the endoplasm, by absence of chromatophores, and in most cases, by the absence of plastids. The absence of cytoplasmic intra-cellular substances makes *Chilomonas* particularly favorable for nuclear study as well as for the study of cytoplasmic structure. The nucleus is a conspicuous body in the lower half of the cell just below the middle line. It is always irregular in outline, the irregularity being due to prolongations of its substance, like pseudopodia, into the adjacent protoplasm. We again find the granular chromatin and the intra-nuclear deeply-staining body. In this case, there is, in all probability, no nuclear membrane, and from the various shapes of the nuclei in different individuals it is inferred that the chromatin granules may become more or less scattered, although remaining in the vicinity of the central body. During division of the cell the chromatin becomes closely aggregated around the central body which divides first, the chromatin granules, as in *Euglena*, separating later into two equal portions. Division here is not as complicated, however, as in *Euglena*, for the chromatin granules do not fuse into distinct rods or chromosomes as in the latter form (Figs. 9 and 10).

Trachelomonas. Several species of *Trachelomonas* were examined and in all cases the nuclei were of the same type as those already described. Among the most noteworthy were the nuclei of *T. lagenella*, *T. volvocina* and *T. hispida*. The simplest of these was found in *T. lagenella* (Fig. 11) where, as in *Chilomonas*, it consists of an irregular mass of chromatin granules surrounding a central body. No nuclear membrane was seen, although the protoplasmic structure was plainly apparent. Compared with the entire nucleus the central body in this case is quite small.

Two varieties of *T. hispida*, which for convenience I shall characterize as variety A, and variety B present two distinct phases of nuclear arrangement. The two forms differ in other respects; variety A is smaller, has no collar, has a comparatively thick shell and is provided with fine, needle-like spines (Fig. 12). Variety B has a collar bearing six distinct spikes on its outer margin. Its wall is comparatively thin and is provided with spines of thorn-like structure, *i. e.*, with broad bases and sharp points (Fig. 13). In both cases the protoplasm is characterized by great vacuoles in which lie a varying number of plastids. The nucleus in variety A resembles that of *T. lagenella* in having an irregular mass of chromatin granules. The edge of the mass is irregular and more or less "frayed out," leaving little doubt as to the absence of a nuclear membrane. The central body is comparatively small and is either round or elliptical in form. The nucleus of variety B, on the other hand, presents quite a different appearance. It is very regular in outline, the margins are smooth and even, and a delicate though distinct membrane encloses it. The central granule is large and conspicuous (Fig. 13).

In *Trachelomonas volvocina* the nucleus resembles that of *T. hispida* variety B. The cell is somewhat more compact however, the nucleus is smaller and the cytoplasm contains more plastids (Fig. 14).

Euglena viridis (Pl. XXXV, Figs. 17, 18, 19). *Euglena*, of the same family as the *Trachelomonads* has, perhaps, the most highly differentiated nucleus of the intermediate type. Blochmann ('94) and Keuten ('95) described this nucleus as a group of chromatin granules enclosed by a membrane, and surrounding a central body—the "nucleolus-centrosome." Each chromatin granule was described as a "*Stäbchen*" or rod-like element. Bütschli ('90) had described, in addition to the chromatin granules and central body, a more or less distinct linin network which was apparently overlooked by Keuten. This so-called linin substance is extremely difficult to see but in thin sections and with the use of oblique light can be made out as delicate fibrils running from granule to granule. This structure could not be seen in the shelled euglenoids (*Trachelomonas*), possibly because the nuclei were not so easy to study, being total preparations of shelled forms. In other monads, as for example *Chilomonas*, which are as easy to study in total preparations as the thinnest of sections, no such fibrils could be made out, although an occasional microsome between the chromatin granules aroused the suspicion that the latter are laid down on the cytoplasmic reticulum, in which case the inter-chromatin cytoplasmic net might be called linin in view of the connection which has been established between cytoplasmic and nuclear networks in the Metazoa.

In *Euglena* the central granule apparently exerts an attractive force during division. The chromatin granules aggregated in the form of small rods—primitive chromosomes—are arranged about it radially. The entire nucleus is surrounded by a delicate though distinct membrane.

Although the structure of the nucleus of *Euglena* and its behavior during cell division have been carefully described by Keuten, the differences between the chromatin and the central body do not seem to have been sufficiently brought out. A carmine stain, for example, is not sufficient to distinguish chromatin from plasmosomes and from the results shown by the iron-hæmatoxylin stain the central body would appear to be chromatin. A very delicate differential result is obtained by the use of the Biondi-Ehrlich mixture of methyl green and acid fuchsine (Auerbach's formula). After this stain the central body is distinctly red and shows out in marked contrast to the green of the surrounding chromatin. From this reaction it follows that the chemical composition of the central body is different from that of chromatin, a result which brings this body even more closely in line with the attraction sphere of the higher forms.

At this point Schaudinn's observations on *Paramœba Eilhardi* are interesting and important. *Paramœba* is a rhizopod with flagellate swarm-spores. The spores resemble *Chilomonas* in general appearance, but a peculiar *Nebenkörper* is found in the former which is lacking in the latter. This body is outside the nucleus which, although it seems to have no nuclear membrane, is nevertheless distinctly marked off from the rest of the cytoplasm. During cell-activity the *Nebenkörper* assumes a dumb-bell shape and, when the ends are well separated but still held together by a connecting rod of its own substance, the chromatin granules begin to migrate towards the center of the connecting rod and finally form a complete ring around it. The *Nebenkörper* is thus a central body similar to the central body of *Euglena* at a corresponding stage in division (cf. Figs. 17, 18, 19). After division of the chromatin the daughter-nuclei are reformed, but in each case the central body is left out in the cytoplasm. This phenomenon recalls the conditions in *Tetramitus* where a similar protoplasmic body acts in a very similar manner (cf. Figs. 1 to 5). The latter form is more primitive however, for the chromatin is not collected in a definite body—the nucleus—but is distributed throughout the cell and collects only during and for cell division.

PROTOZOAN NUCLEI OF TYPICAL METAZOAN STRUCTURE.

A typical metazoan nucleus differs from the forms described above in having a distinct linin reticulum with chromatin laid down within it and forming a chromatin reticulum; often a more or less clearly differentiated nucleolus, and a nuclear membrane which usually disappears during mitosis. Many important differences are found when a comparison is made of the nuclei during division. In the majority of Metazoa there is a distinct spirem leading up to the formation of chromosomes in each case characteristic of the species; and distinct spindle-formation with centrosomes and spindle fibers. In the Protozoa a number of nuclei have been described which agree more or less closely with the requirements of such a nucleus. So far as the resting nucleus goes, *Actinosphærium* and the nuclei of some Sporozoa are similar to the Metazoan nuclei while the nuclei of *Actinophrys* and of *Euglypha* approach them in mitosis. The number of such cases, however, is very small and, when compared with the number showing the intermediate type, it is insignificant. In short, the vast majority of Protozoa excluding the infusoria possess various conditions of nuclei of the intermediate type.

ABERRANT TYPES OF PROTOZOAN NUCLEI.

While nuclei of the type described above in flagellates seem to lead by gradual stages into more complicated forms of the Metazoan type, other nuclei of the Protozoa seem to have developed along a divergent path and finally resemble only remotely the primitive forms on the one hand, and the higher forms on the other. These nuclei may be described as aberrant forms, although the number of such forms is probably greater than any other type among the Protozoa. In most cases, however, the structure can be traced back to more primitive forms of the "Intermediate type." A few examples which have come under my own observation must suffice. These are *Amœba proteus* among the Rhizopoda, *Ceratium* and *Peridinium* among the Dinoflagellata, *Noctiluca*, a Cystoflagellate, and *Stylonychia* among the Ciliata.

Amœba proteus (Fig. 16). The nucleus of this common rhizopod is of large size and of characteristic shape, resembling a biconcave disc. It is constant in shape and is bounded by a firm membrane which, together with the granular chromatin contents, can be easily made out while the animal is alive. The finer structure, however, is seen only in sections which, with these large forms, can be cut in any desired plane. The nucleus contains, in addition to the general ground substance, or nuclear sap, two kinds of staining substances one of which becomes intensely black with iron hæmatoxylin, while the other is gray. The more deeply staining substance is chromatin in the form of granules distributed throughout the nucleus; the other substance has the form of a disc lying in the center of the nucleus. Gruber ('83) calls this central mass the "nucleolus." In all of the specimens which I examined at this time the nucleus had the same structure and I am convinced that it is typical of *Amœba proteus*. The faintly staining central mass is perfectly homogeneous in structure and, although I have not seen it in division, I am confident that it is to be compared with the intranuclear body in the flagellates. In other species of *Amœba* the nucleus possesses an internal structure similar to the "nucleolus centrosome" of *Euglena* (Schaudinn, '94).

The nucleus of *Amœba proteus* can be regarded as similar to that of *Chilomonas* plus a nuclear membrane. There is no evidence of other intra-nuclear bodies such as linin, nucleoli, etc., nothing is present but chromatin and the central body. The tough nuclear membrane is possibly due to the peculiarly rough treatment which the nucleus undergoes in its cyclosis with the other endoplasmic substances.

Ceratium and Peridinium. Bütschli ('85) found a very curious structure in the dinoflagellate nucleus. Viewed from one side it appears to be of the regular reticulate type with local thickenings on the linin network ; but, looked at from another side, the nucleus seems to be composed of rows of chromatin connected by delicate fibrils, the whole having a more or less honey-comb structure. Lauterborn ('95) confirmed Bütschli's description but added that the nucleus invariably contains one or two nucleoli, and that in division a peculiar rod-like body of "unknown significance" stretches across the division axis. Lauterborn is inclined to believe this structure homologous with the intra-nuclear body of *Euglena.* I have examined a number of Dinoflagellata from Puget Sound and Alaska including *Peridinium divergens*, *Dinophysis*, *Ceratium tripos*, *Ceratium fusus*, etc. and in all of them I have found the familiar intra-nuclear central body, differing however from the more frequent type in being sometimes single, sometimes double or multiple. (Figs. 21 *Peridinium divergens*, and 20 *Ceratium fusus.*) The peculiar rod-like or even lamellate structure of the chromatin is perhaps due to the fusion of chromatin granules, thus forming a permanent structure comparable to a spirem.

Noctiluca miliaris (Pl. XXXV, Figs. 22–26). Of very different structure is the nucleus of *Noctiluca miliaris*, a form possibly allied to the Dinoflagellata. The chromatin here is massed in from eight to eleven large reservoirs (Fig. 22), while the rest of the nucleus is filled with a granular substance of quite a different chemical composition. The whole is enclosed in a firm membrane. This nucleus would be difficult to understand were it not for the changes which the chromatin undergoes previous to division. The large reservoirs disintegrate during the earlier stages of mitosis, forming smaller and smaller chromatin bodies, the final result being a great number of minute chromatin granules, which, as in *Chilomonas* or *Euglena*, are found distributed throughout the nucleus. The chromatin granules later unite to form distinct chromosomes. The formation of the chromosomes is entirely different from the account of the process given by Ishikawa ('94). The granules of chromatin unite in lines which are focussed at one side of the nucleus; these lines are the chromosomes, and they are subsequently divided through the agency of a complicated mitotic process in which centrospheres, central spindles and centrosomes play an important part.[1] In the early stage of division, when the chromatin is scattered throughout the cell in the form of minute chromatin granules, the nucleus of *Noctiluca* is obviously comparable with the nucleus of the intermediate type, while the vegetative condition can be conceived as due to the coalescence of the chromatin granules to form the large reservoirs. An essential difference in the nucleus of *Noctiluca*, however, is found in the absence of an intra-nuclear central body. The place of this important mitotic agent is taken by a large cytoplasmic sphere lying just outside the nuclear membrane. This sphere, during mitosis, plays the same part as the intranuclear body of the lower flagellates, but in a much more complicated way. While the chromatin granules are fusing to form the chromosomes the sphere divides to form a dumb-bell shaped body consisting of two daughter-spheres and connecting fibrous substance forming the "central spindle" (Fig. 23). The nucleus then bends around in the form of a U until it almost completely surrounds the central spindle. The chromosomes, focussed at the side of the nucleus which was turned towards the cytoplasmic sphere, now form a nearly continuous line or ring—the nuclear plate—around the central spindle (Fig. 23). At this period it can be found by sections that the nuclear membrane has disappeared from that portion of the nucleus between the chromosomes and the central spindle, and that the ends of the chromosomes are connected by distinct fibers—the mantle fibers—with centrosomes inside of the spheres (Figs. 24, 26). The chromosomes are then divided longitudinally beginning at the ends turned towards the central spindle, and one-half of each chromosome goes to form the daughter nuclei. The nuclei are reconstituted by the subsequent aggregation of the chromatin granules into the large reservoirs while the sphere in each case forms a definite body on the outside of the nucleus.

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[1] For a description of the process of mitosis in *Noctiluca* see my paper, now in press, which will shortly appear in the *Journal of Morphology* on "Mitosis in *Noctiluca miliaris* and its Bearing on the Nuclear Relations of the Metazoa and the Protozoa."

The staining reactions of the sphere in *Noctiluca* are the same as those of the intra-nuclear body in *Euglena* and *Chilomonas*, and the same as the cytoplasmic body in *Tetramitus*. During mitosis its history is remarkably similar to that of the *Nebenkörper* as described by Schaudinn ('96) in the case of *Paramœba*. I think therefore that there can be no doubt that the sphere in *Noctiluca*, the *Nebenkörper* in *Paramœba*, the cytoplasmic body in *Tetramitus*, and the intra-nuclear body of *Euglena*, *Chilomonas* and allied forms are all analogous structures and have the same physiological part to play in the activities of the cell.

The sphere in *Noctiluca* however possesses an element during division which has hitherto not been found in the corresponding intra-nuclear or cytoplasmic bodies described above. This element is a distinct centrosome which was first described for *Noctiluca* by Ishikawa and the presence of which I have demonstrated beyond question. In addition to the centrosomes furthermore there is a second set of fibers—the mantle-fibers—which connect the chromosomes with the centrosomes; nor have these been found in the simpler nuclei described above.

A number of the Protozoa agree with *Noctiluca* in the history of the chromatin, and several observers (Gruber, Hertwig, Brauer) have described the breaking down of large chromatin reservoirs or "nucleoli" as they have been erroneously called.

When we come to consider the nuclei of the Ciliata and the Suctoria we are met by a new difficulty. The nuclei are dimorphic, and the two forms differ as much in structure as they undoubtedly do in function. I have no new observations to record on the structure of micro- and macronuclei, but it is possible that the facts given above may throw some light on their origin. A number of theories have been advanced to explain the origin of the micronucleus and the aberrant type of nuclei in the Infusoria in general. The usual form of theory is that the two types gradually arose by differentiation of a primitive bi-nucleated form, one of the nuclei becoming the micronucleus, the other the macronucleus (Bütschli, Lauterborn, etc). A serious objection to this theory is that the macronucleus is formed from one of the subdivisions of the micronucleus at each conjugation. Schaudinn suggested in his paper on *Paramœba* ('96) that the micronucleus and macronucleus of the Infusoria might have arisen from the *Nebenkörper* and nucleus respectively of forms like *Paramœba.* The possession of chromatin by the micronucleus is a serious obstacle to this theory, and yet the important part which the micronucleus plays in reproduction makes Schaudinn's suggestion valuable. If pure hypothesis be allowed it might be conceived that the micronucleus represents the cytoplasmic body of forms like *Tetramitus* and *Paramœba* plus a certain amount of chromatin while the macronucleus represents the nucleus with the remnants of chromatin minus the essential cytoplasmic body. The cytoplasmic body which appears to be essential to reproduction as shown by its universal presence, is found, in most cases, in only one of the nuclei, which persists, while the other degenerates.

General Conclusion.

Enough has been given above, I believe, to show that a type-form of nucleus can be found to which the nuclei of the various groups of Protozoa can be compared; divergent forms being explained as modifications of this type. Such a nucleus can be described in brief as consisting of two distinct substances, one of which acts as an "attraction" center, the other as chromatin in the form of granules. From this primitive type two lines seem to have developed, in one of which the attraction center remains outside of the nucleus (*Noctiluca*, *Paramœba*) while in the other it is intra-nuclear (Euflagellata). The significance of the central granule as an attraction-center in the case of *Euglena* was early recognized by Bütschli ('87), Blockmann ('94), Keuten ('95), Lauterborn ('95) and others who saw in it a primitive centrosome. Hertwig more recently ('96) accepted the idea and explained the central body in *Euglena*, together with the large spheres in *Noctiluca* and the pole-plates found in various Protozoa as centrosomes of the type observed by himself in sea-urchin eggs after treatment with various salts. I have shown above, however, that the sphere in *Noctiluca*, the cytoplasmic body of *Tetramitus*, the *Nebenkörper* of *Paramœba* and the intra-nuclear body of *Chilomonas*, *Euglena* and allied forms are analogous structures and that they have the same physiological function to play in the activity of the cell. But it has also been shown that there is a true centrosome in the sphere of *Noctiluca*. The intra-nuclear body of *Euglena* therefore cannot be called a centrosome as the above-named observers have designated it, and cannot be compared with the centrosome of the Metazoa. It is comparable however with the cytoplasmic bodies of *Paramœba*, of *Noctiluca*, and therefore with the attraction-sphere of metazoan nuclei. Moreover, this element seems to arise in the simplest cases as a cytoplasmic structure and independently of chromatin or nucleus (*Tetramitus*). It appears therefore that Boveri's original conception of an independent cellular substance, the archoplasm, holds good in the case of the Protozoa. By considering the intra- or extra-nuclear body of Protozoa as archoplasm in the form of an attraction sphere, rather than as a centrosome, the various conflicting views in regard to these structures can be more or less brought together. By this view can be explained the origin and significance of the central spindle of the Metazoa (cf. *Centrodesmus* of Heidenhain); the origin of spindles without centrosomes in the higher plants (cf. Strasburger's *Kinoplasma*); and, to some extent, the various interpretations of the function, origin and fate of the centrosome. According to this view the centrosome is originally of minor importance, the sphere alone being functional as an attraction center. The centrosome appears to be of later origin, although even in the higher tissues, as Flemming ('97) suggests, it is apparently not an organ of primary importance, but an organ which may be present in connection with cell-divisions, although not necessary for it.

There is also good evidence in this study of primitive nuclei to show that the common type offers an explanation of the changes which the constituents of the metazoan nucleus undergo during and preparatory to a division. Stated briefly this idea may be expressed as follows: (1) Before forming chromosomes the chromatin material of the metazoan nucleus is distributed in the nucleus in the form of minute chromatin granules, a stage representing the ancestral condition which in flagellates and lower plants is permanent; (2) the chromatin granules (Brauer, '93 *Ascaris*) secondarily fuse to form distinct bodies—the chromosomes—of definite form and number for each species; (3) the chromatin is in close connection with the kinetic center (centrosome or centrosphere plus central spindle), to accomplish this connection the nuclear membrane disappears (in most Protozoa the attraction sphere is inside the nuclear membrane and so in constant connection with the chromatin; in other forms of Protozoa where the attraction sphere is extra-nuclear as in *Noctiluca* and *Paramœba* the membrane disappears on the side of the nucleus nearest the sphere—*Noctiluca*—or there is no membrane at all—*Paramœba*). In all cases the chromatin at the time of division is collected around or between the spindle fibers, or in case of Protozoa, the attraction-sphere, possibly to ensure a more perfect division of this important substance.

SUMMARY OF OBSERVATIONS AND CONCLUSIONS.

1. Metazoan and protozoan nuclei cannot be strictly homologized, but it can be shown that an intermediate series of forms connect them.

2. The nuclei of Protozoa are not all of the same type and in some forms they may possibly be absent. The simplest structure is the distributed nucleus, consisting of isolated chromatin granules scattered about the cell.

3. A higher type is shown by the "intermediate" nuclei, where the chromatin granules are massed together in a compact form with or without a nuclear membrane (most Euflagellates).

4. Typical nuclei of the metazoan type are uncommon among the Protozoa, but are occasionally found.

5. Nuclear differentiation in Protozoa is closely connected with an attraction-sphere or active agent in division. In nuclei of the distributed type this is an indefinite faintly staining cytoplasmic mass in the vicinity of which the scattered chromatin granules collect previous to division and about which they are grouped during division. In nuclei of the "intermediate" type the attraction-sphere is intra-nuclear, definite in form, deeply staining and active, and chromatin granules are massed about it either permanently (*Synura*, *Chilomonas*, *Englenoids*, etc.) or only during division (*Paramœba*), and with or without a nuclear membrane. In higher types of nuclei the attraction-sphere is no longer intra-nuclear, but this position of vantage is taken by the central spindle during division (*Noctiluca* and many Metazoa).

6. The intra-nuclear body of *Euglena* and other allied forms is equivalent to the attraction-sphere and not to the centrosome of the metazoa.

7. Chromosome-formation is first seen in the flagellates in the form of rods which arise by the union of the previously scattered chromatin granules. They form in typical though primitive metazoan manner in *Noctiluca* and *Euglypha* and all Metazoa pass through these stages in preparing for mitosis.

Columbia University, April, 1898.

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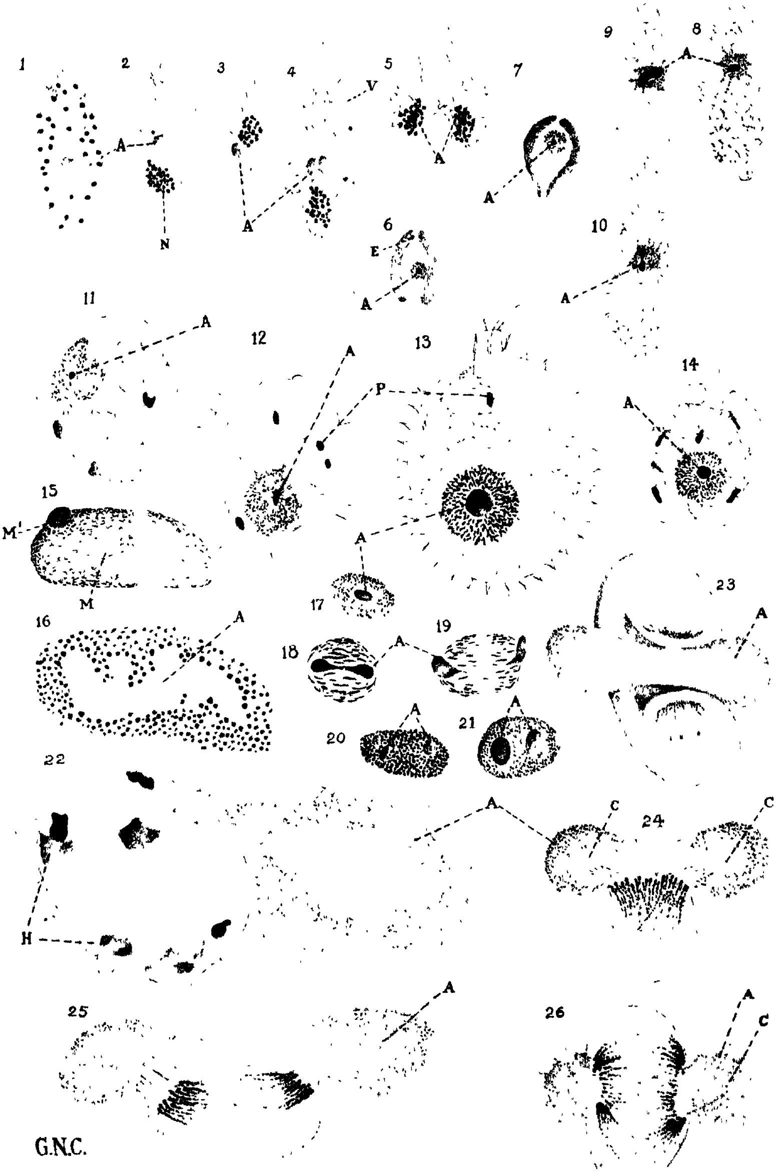
PLATE XXXV.

PLATE XXXV.

PROTOZOAN NUCLEI.

Figs. 1–4. A flagellate Protozoan of genus **Tetramitus,** showing "distributed nucleus"—(N), and a compact alveolus—(A). See page 382
Fig. 5. The same form of **Tetramitus** undergoing division. See page 383
Fig. 6. **Microglena punctifera.** E = Eye spot. See page 384
Fig. 7. **Synura uvella.** See page 384
Figs. 8–10. **Chilomonas cylindrica** EHG. See page . . 385
Fig. 11. **Trachelomonas lagenella.** See page 385
Fig. 12. **Trachelomonas hispida var.** A. See page . . 385
Fig. 13. **Trachelomonas hispida var.** B. See page . . 385
Fig. 14. **Trachelomonas volvocina.** See page 386
Fig. 15. Macro- and micronuclei of **Stylonichia.** See page 388
Fig. 16. **Amoeba proteus.** See page 389
Figs. 17–19. **Euglena viridis.** See page 386
Fig. 20. **Ceratium fuscus.** See page 390
Fig. 21. **Peridinium divergens.** See page 390
Figs. 22–26. **Noctiluca miliaris.** See page 390

PLATE XXXV.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[ANNALS N. Y. ACAD. SCI., XI, No. 17, pp. 401 to 403, October 13, 1898.]

A SIMPLE AND CONVENIENT PHOSPHOROSCOPE.

WALLACE GOOLD LEVISON.

(Read April 4, 1898.)

IN Wright's *Light*[1] there is a description of a phosphoroscope designed for lecture illustration which is attributed to Professor John Tyndall. It consists of a cylinder set in revolution by a crank mechanism before a slit in a light-tight box, through which the light from an electric arc lamp enclosed in the box falls upon the cylinder. The cylinder being coated with coarsely pulverized uranium glass, the audience, in a dark room observes a band of green light across the cylinder the intensity of which increases in proportion to the rapidity of its revolution. This is due to light absorbed by the uranium glass as it passes the slit, and given forth so deliberately as to be still escaping during the time required for more than a half revolution of the cylinder.

Having occasion to use some such simple contrivance in a recent investigation upon this property[2] of minerals, I constructed a modified form of this instrument consisting of a hollow pasteboard cylinder, set in revolution by an electromotor, whereby much greater speed is attained than by a mechanical device. Instead of coating the cylinder directly with the mineral to be examined I dust it in coarse or fine powder upon the surface of sheets of paper brushed over with hot gelatine. These fold around the cylinder and fasten with rubber bands, and are, therefore, interchangeable at pleasure. In other cases I simply fix a single piece of a mineral, either transparent or opaque, upon the surface of the cylinder. At the great speed attained by the electromotor, bands of light are thus obtained from certain minerals which afford perhaps a shorter afterglow than uranium glass. In one or the other of these ways I have obtained a band of green light from willemite, from Franklin, N. J., and a band of crimson light from corundum, from near Franklin, Macon Co., N. C. I have no doubt that other minerals affording too short an afterglow to be at all pronounced with the cylinder revolved by a hand power motor, would be effective with my light cylinder set in rotation at the high speed of an electromotor.

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[1] Wright (L.), *Light*, London, 1882.

[2] For which the term photofluorescence, in view of the recent experiments of Wiedemann and Schmidt seems to me best adapted.

By further modification the apparatus may be used in two other ways. The hollow pasteboard cylinder employed is closed by a solid wooden block at the end which is fixed upon the axle of the electric motor. The other end may be closed with a paper cover, or left open; in the former case I attach to the inside of this cover[1] a spring forceps, by means of which an object such as a diamond, a ruby, or a piece of willemite may be held exactly in the center of the cylinder. The cylinder is provided with a side opening through which the light from a lantern condenser may be focused upon the object in the center of the cylinder when the opening is on the side away from the observer, and through which the side of the object just previously illuminated, may be seen by the observer wholly screened from any light whatever, when the opening is on the side of the cylinder toward the observer. If the object be thus examined in a totally dark room and affords no afterglow, nothing whatever is seen; but if it affords an afterglow, it becomes visible owing to the persistence of vision, with a characteristic colored light when the cylinder rotates with sufficient speed, and its brilliancy increases as the speed of rotation of the cylinder further increases.

In the latter case a similar spring forceps supported upon a suitable stand is introduced through the open end of the cylinder to hold the object, which, therefore, does not partake of the motion of the cylinder. The first form is adapted to both transparent and opaque objects, the latter more particularly to transparent objects which, being at rest, are more distinctly seen; an advantage in the case of cut gems.

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[1] Modification adopted since the paper was read. Exhibited at the Annual Reception of the Academy [Physics, No. 7], April 13, 14, 1897.

In one or the other of these ways I have obtained beautiful results from uranium glass, cut rubies, semi-transparent corundum and willemite. I have not yet had an opportunity to try a diamond affording an afterglow.

It is evident that both opaque and transparent substances may be examined by this instrument, either fixed upon the outside of the cylinder, or held within it, as described; and in either case its indications are quite sensitive, inasmuch as it may be given so high a speed that only a very small fraction of a second elapses after the object is illuminated and before its presentation in absolute darkness to the eye of the observer. Moreover, in either case, one object may be substituted for another quickly and easily, and the brilliancy obtained from some minerals, especially rubies, is quite surprising.

[ANNALS N. Y. ACAD. SCI., XI, No. 18, pp. 405 to 406, October 13, 1898.]

PHOTOGRAPHED OCULAR MICROMETERS.

WALLACE GOOLD LEVISON.

(Read April 4, 1898.)

OWING probably to the difficulty of starting and stopping ruling machines at cross lines without overrunning them, it has been found difficult to obtain eye piece micrometers ruled in squares, particularly of the design now so much used in water supply investigations for counting and measuring micro-organisms.

It occurred to me that these micrometers might be made easily by photography, and as a test experiment I made some of them by the ordinary simple dry-plate method with some precautions to ensure clear films. An outline drawing 14 centimeters square was first made with India ink and an ordinary drawing pen upon glass coated with gelatin, and one-half the square in each direction was ruled in five equal parts. The small central square formed by the crossing of these lines was then divided by cross lines into twenty-five equal areas according to the plan given in Prof. Albert R. Leed's report on the Brooklyn water.[1]

This drawing was photographed down by an ordinary one-quarter portrait lens with small diaphragm stop, to about five centimeters square on a Stanley dry plate, care being taken to obtain as nearly as possible a black negative with very clear lines. For each micrometer this is again reduced by the same lens to a square of seven millimeters on lantern slide plate, care being taken to develop the lines black, keep the film transparent and avoid scratches.

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[1] A. R. Leeds, Report on the Brooklyn Water, published by the Department of City Works of Brooklyn, N. Y., 1897.

The plates thus obtained are cut in circles a little larger than the recess in the eye piece diaphragm in which they are to be used. A cover class is then applied with balsam and xylol and baked for several days until the cement is hard and dry. The circle is finally accurately centered on a lathe and ground to a true circle of the exact size of the recess in the eye piece diaphragm.

In making these photographs the action of halation will cause the lines to be much thinner in the negative than in the original drawing and thicker in the finished positive than in the negative, and moreover it will cause a peculiar thickening where the lines intersect unless the precautions known to expert photographers are employed at each step to counteract this peculiarity of the photographic process.

But even if not wholly obviated, this does not materially interfere with the practical utility of the micrometer. I have no doubt that very accurate and beautiful micrometers may be thus made by the so-called process method which is a wet plate method used for making photo engravings as it affords jet black lines on a particularly clear ground. The lines as I have made them are thicker perhaps than is necessary, but this does not appear to interfere with the use of the micrometer, providing distances are taken from one side of a line to the same side of the next line, and so on throughout the scale.

Eye piece micrometers made by the simple method I have tried appear to be satisfactory for use with any objective, as regards transparency. In fact they seem in some respects to be more satisfactory than ruled micrometers, especially in the circumstance that the lines are black and always distinctly visible and that they can be made with facility of any design desired. For the latter reason they may be valuable not only for measuring micro-organisms but also any class of microscopic objects whatever, as for example the areas of the crystals or grains of minerals in thin sections of rocks and building stones and thereby perhaps estimating their relative proportions.

[ANNALS N. Y. ACAD. SCI., XI, No. 19, pp. 407 to 413, October 13, 1898.]

NOTES ON BERMUDA ECHINODERMS.

HUBERT LYMAN CLARK.

(Read May 9, 1898.)

THE collection of echinoderms made in Bermuda in the summer of 1897 by the New York University party, has been very kindly placed in my hands by Professor Bristol, for examination. Although the collection is in itself a small one, it is of no little interest, as our present knowledge of the echinoderms of Bermuda is very incomplete. So far as I can discover, no attempt has hitherto been made to prepare a complete list of them, so that it has seemed worth while to add to the species in the New York University collection, others which have previously been recorded from the islands, thus making as far as possible a catalogue of the littoral echinoderms of Bermuda. In 1888, Professor Heilprin, of the Philadelphia Academy of Sciences, published in the *Proceedings* of that Academy, a list of the echinoderms, which he and a party of students had collected in Bermuda that summer. The list contains twenty species, six holothurians, six echinoids, six ophiurids and two asteroids. Of the six holothurians, four are described as new to science. The New York University collection contains only eleven species, but of these at least three are additions to Professor Heilprin's list. The principal interest of the collection, however, lies in the light which it throws on Professor Heilprin's "new" species of holothurians, and on one of Professor Verrill's species of starfish.

There are only two species of ASTEROIDS in the collection, but both are of interest. One of them, of which ten specimens lie before me, is the common starfish of the Bermudas. One of its peculiar features is the great variation in the number of arms, one specimen having nine, five having seven and the other four six, while Professor Heilprin reports having found one or two specimens with only five. The specimens I have agree in every particular with the most careful descriptions of *Asterias tenuispina* Lamk., from the Mediterranean and eastern Atlantic, and, I have no doubt, belong to that species. Verrill has separated the *Asterias* of Bermuda from *A. tenuispina* as *A. atlantica*, on the ground that the proportions of the arms are slightly different and that there are no large single pedicellariæ. Sladen, in his report on the starfishes of the "Challenger" collections, identifies the only *Asterias* from Bermuda as *A. tenuispina* and questions the authenticity of Verrill's species. In the specimens before me the proportions of the arms vary considerably and large single pedicellariæ occur in the ambulacral furrow as in *A. tenuispina.* Accordingly it would appear that *A. atlantica* must be regarded as a synonym of that species. In several of the New York University specimens the prominent spines on the upper surface are rather unusually colored, being strongly tinged with violet. The other starfish, of which there are five specimens in the collection, is *Asterina folium* Ltk., a small pentagonal species found closely adhering to the under side of broken pieces of rock. They are very light colored, almost white, but one is strongly tinged with blue. They agree in all particulars with specimens of the same species from Jamaica.

The two OPHIURIDS are of no especial interest, though one of them has not previously been taken in Bermuda. This is *Ophiura appressa* Say, of which there are three specimens in the collection. They were kindly identified for me and compared with Jamaica specimens by my friend, Mr. Caswell Grave, of the Johns Hopkins University. Of the other species, *Ophionereis reticulata* Ltk., there is a large number of specimens. It seems to be the common brittle-star of the islands.

The four ECHINOIDS are all reasonably common in suitable places, Professor Bristol tells me, and have all been recorded from Bermuda before. They are *Diadema setosum* Gray, *Echinometra subangularis* Leske, *Hipponoë esculenta* Leske and *Toxopneustes variegatus* Lamk. Anyone familiar with the latter urchin as it appears in Jamaica or along our southern coast would never recognize it in these handsome specimens from Bermuda. A close examination, however, shows that the great difference in color is only one of degree. Specimens from Jamaica are green with white markings and with whitish or greenish spines, the latter being often tipped with violet. Now in the Bermuda *Toxopneustes*, violet has become the predominant color, so that all trace of green and white variegation has disappeared. The test has become very dark and the spines are a bright purple violet. This tendency towards violet coloration of spines has already been mentioned in connection with the starfish, *Asterias*, and it is also quite marked in one of the other sea-urchins, *Echinometra*. Specimens of this form from Jamaica are usually reddish-brown of some shade but the spines are often greenish, tipped with violet. Bermuda specimens show this violet coloration of the spines much more plainly. It would be interesting to know what may be the cause of this tendency toward violet among the Bermuda echinoderms; but I have no explanation to offer.

There are only three species of HOLOTHURIANS in the collection but all of these are of considerable interest because of the light which they throw on the "new" species described by Professor Heilprin. Professor Bristol's students report that there are two large species of *Stichopus* common at the Bermudas, and that they are readily distinguishable from each other. This statement agrees with Professor Heilprin's, who has described and figured each of them as a new species. One of them is black and was called *S. diaboli*, but I am sorry to say that of this species there is not a specimen in the collection before me. The other one is less common, is markedly different in color, and was given the name *S. xanthomela* Heilprin. Of this species, I have two specimens in hand, one of which agrees perfectly in color with Professor Heilprin's description, while the other is much darker. It needed but a glance to see that they are the common West Indian form of *Stichopus*, though what that form is to be called it is not easy to decide. A more careful examination of the Bermuda specimens has shown that they agree in all particulars with specimens from Jamaica. After a careful examination of hundreds of specimens of *Stichopus* from Jamaica, both living and alcoholic, I am convinced that specific differences cannot be distinguished in this genus with any accuracy except in living specimens, and furthermore that coloration is so variable that it is almost useless as a standard in classification. Four species of *Stichopus* have been described from the West Indian area, all of them from alcoholic material, by men who have never visited the West Indies, and they are separated from each other by characters which are seen in a large series of specimens to intergrade in inextricable confusion. For the present however, the commonest West Indian species may bear the name *S. möbii*, bestowed by Semper, and Heilprin's *S. xanthomela* is doubtless the same. According to the latter the Bermuda form has eighteen tentacles, but both of the specimens before me have twenty, while one Jamaica specimen has nineteen and another twenty-one. The normal number of tentacles in *Stichopus* is however twenty, and any other number is merely an individual peculiarity.

The second species of holothurian from Bermuda in my hands is a small one, occurring under broken slabs of rock, and of this there are six specimens. I have compared them with more than a dozen species of small holothurians collected in Jamaica in similar situations, but they do not agree with any of them satisfactorily. After some hesitation, I have decided to refer them provisionally to Ludwig's *Holothuria surinamensis*, as they approach nearest to that species, though the differences are pretty clearly marked. I think it probable that a larger series of specimens will show the Bermuda form to be a new species. Professor Heilprin collected five specimens of a small holothurian, which he refers to *H. floridana* Pourt., but neither in his description nor his plate does he refer to the small rosette-like calcareous bodies, so characteristic of that species and its allies. If they are not present in his specimens, I should think it at least possible that these are the same species as the ones before me. The last of the three species in the New York University collection is obviously either a *Thyrne* or a representative of that section of *Cucumaria* to which Lampert gave the name *Semperia*. There are two specimens about 6 cm. long and agreeing in all particulars with each other. After a careful examination I refer them without hesitation to Ludwig's *Cucumaria punctata*, described from a specimen collected in Barbadoes. In a few details they differ from that species: the color being apparently different, the stone canal free, only one polian vessel, and the anus armed with five small calcareous teeth. The calcareous buttons are so numerous in some places that the skin is very hard, the layer of buttons being .4 mm. thick. Professor Heilprin describes from a single specimen a new species of *Cucumaria* which he calls *Semperia bermudiensis*. While I have no way of proving that this is the same species as the specimens before me, the differences which he points out between it and Ludwig's *C. punctata* do not seem to me important, and I strongly suspect that *S. bermudiensis* Heilp. ought to be put down as a synonym of *C. punctata* Ludw. I am at a loss to understand what Professor Heilprin means by the "long back processes" of the calcareous ring "for the attachment of the powerful retractor muscles." So far as I know the retractor muscles of *Cucumaria* and *Thyrne* are never attached to the *posterior* prolongations of the radial pieces of the calcareous ring but always to *anterior* prolongations. The latter are quite long in *Cucumaria punctata*.

In the light of these facts, I append the following revised list of the littoral echinoderms of Bermuda, as complete as I have been able to make it. It does not pretend to include the deeper water species collected in the vicinity of the islands by the "Challenger."

CATALOGUE OF THE LITTORAL ECHINODERMS OF BERMUDA.

ASTEROIDS.

1. **Asterias tenuispina** Lamk. = *A. atlantica* Verrill. Common. Collected by all parties.

2. **Asterina folium** Ltk. Not very common. One specimen collected by the "Challenger" and five by the New York University party.

3. **Linckia guildingii** Gray. Apparently not common. Recorded by Sladen in the "Challenger" report and by Professor Heilprin.

OPHIURIDS.

4. **Ophiactis mülleri** Ltk. Two specimens collected by the Philadelphia party.

5. **Ophiocoma crassispina** Say. One specimen taken by the Philadelphia party.

6. **Ophiocoma pumila** Ltk Collected by the "Challenger" and by the Philadelphia party.

7. **Ophiomyxa flaccida** Ltk. One specimen taken by the Philadelphia party.

8. **Ophionereis reticulata** Ltk. Abundant. Recorded by all parties.

9. **Ophiostigma isacantha** Say. Two specimens taken by the Philadelphia party,

10. **Ophiura appressa** Say. Three specimens taken by the New York University party.

ECHINOIDS.

11. **Cidaris tribuloides** Bl. Reported common by the Philadelphia party.

12. **Diadema setosum** Gray. Common. Collected by all parties.

13. **Hipponoë esculenta** Leske. Not uncommon. Collected by all.

14. **Echinometra subangularis** Leske. Common. Collected by all.

15. **Toxopneustes variegatus** Lamk. Common. Collected by all.

16. **Mellita sexforis** Ag. Said to be common, but not actually collected by either the Philadelphia or New York parties. Recorded from Bermuda by Agassiz.

17. **Echinoneus semilunaris** Lamk. Reported from Bermuda by Agassiz in his "Revision of the Echini" and in the "Challenger" report.

18. **Brissus unicolor** Kl. Reported from Bermuda by Agassiz.

HOLOTHURIANS.

19. **Cucumaria punctata** Ludw. Two specimens collected by the New York University party.

20. **Cucumaria (Semperia) bermudiensis** Heilp. A very doubtful species described from a single specimen taken by the Philadelphia party.

21. **Holothuria floridana** Pourt. Five specimens collected by the Philadelphia party.

22. **Holothuria captiva** Ludw. Two specimens collected by the Philadelphia party.

23. **Holothuria abbreviata** Heilp. A very doubtful species described from a single specimen, probably an abnormal individual of the preceding species, collected by the Philadelphia party.

24. **Holothuria surinamensis** (?) Ludw. Six specimens, collected by the New York University party, are referred to this species with much hesitation.

25. **Stichopus diaboli** Heilp. Reported as very common.

26. **Stichopus möbii** Semper. = **S. xanthomela** Heilp. Reported as quite common.

27. **Stichopus haytiensis** Semper. Reported from Bermuda by Dr. Theél from a single specimen collected by the "Challenger." I am inclined to think it may be the same species as the preceding.

28. **Synapta vivipara** Oerst. Recorded from Bermuda by Dr. Theél in the "Challenger" report under the name *S. picta.* Dr. Theél also has numerous other specimens from the Bermudas.

Of the above twenty-eight species, four or five of the holothurians are in doubt, so that the need of larger and more complete collections is very obvious. Of the remaining twenty-two or three species, all but one or two are distinctly West Indian, so that it is only fair to expect the discovery of many more, by more careful and systematic collecting.

[ANNALS N. Y. ACAD. SCI., XI, No. 20, pp. 415 to 430, October 13, 1898.]

ADDITIONS TO THE PALÆOBOTANY OF THE CRETACEOUS FORMATION ON STATEN ISLAND. NO. II.

ARTHUR HOLLICK.

(Read May 16, 1898.)

[PLATES XXXVI–XXXVIII.]

IN two papers upon this subject previously published our knowledge of the Cretaceous flora of Staten Island was brought up to the year 1892.[1] Since that time considerable additional material has been collected, including several species not before recorded from the island, which have been the subject of notes and memoranda read before the Natural Science Association of Staten Island and published from time to time in its Proceedings.

The object of the present paper is to describe this material as a whole and also to indicate certain modifications of views previously expressed, due to information acquired since the other contributions to the subject were issued.

All the specimens were found in hardened ferruginous clay concretions or shaly fragments, in connection with the terminal moraine. None of the specimens was found in place, although they must have been derived from Cretaceous strata in the immediate vicinity, either on the island or on the adjacent mainland. Some of those from Tottenville and Prince's Bay may have been from the latter source, but the Arrochar specimens were undoubtedly native to the island, although disturbed from their original position.

It was previously taken for granted that all the cretaceous strata on Staten Island were continuations of those at Perth Amboy and Woodbridge, and that the fossil plants found in them or derived from them would prove to be identical with those of the mainland. Such, however, has not been found to be the case, and this fact has seemed to indicate that some of the strata from which the Staten Island plants were derived may represent a different and presumably a higher member of the Amboy clay series than do those represented at the New Jersey localities mentioned.

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[1] The Palæontology of the Cretaceous Formation on Staten Island. *Trans. N. Y. Acad. Sci.*, XI (1892), 96–104; Pl. I–IV.

Additions to the Palæobotany of the Cretaceous Formation on Staten Island. *Ibid.*, XII (1892), 28–39; Pl. I–IV.

Many of the species are identical, but a number of those found on Staten Island have not yet been discovered in the New Jersey clays, although these have been quite extensively exploited and hundreds of specimens have been collected from them; and further, some of the species most common in New Jersey are conspicuous by their absence or rarity on Staten Island.

As is well known the Cretaceous clays of New Jersey extend across the State with a general northeast and southwest strike and a dip towards the southeast of about fifty feet to the mile. Those which outcrop furthest to the northwest are therefore the lowest or oldest of the series. If a geological map of New Jersey be examined and the trend of the clay outcrops be theoretically extended on to Staten Island, it may be readily seen that the lower beds, represented by those at Woodbridge, Sayreville, Perth Amboy and possibly South Amboy, would strike the western shore of Staten Island in the vicinity of Tottenville and Kreischerville, while the upper beds, represented by those in the vicinity of Cheesequakes creek, would strike along the southern shore of the island from Tottenville to Arrochar.

This probability is further strengthened by the fact that marl bed fossils have been found in the moraine at the latter locality, showing that strata even higher than the upper members of the clay series are or once were represented there.

From a consideration of these facts and other similar ones in connection with the Cretaceous clays on Staten Island, Long Island, Block Island and Martha's Vineyard, the name "Island

Series" was given by Dr. Lester F. Ward to the strata represented on these islands.[1]

The "Island Series" would therefore lie above the Amboy clays as described by Newberry,[2] and below those of the clay marls at Clifford, as described by me in a recent paper.[3]

The sequence of the strata and their relations to the localities where they are prominently exposed may be understood from the following table:

Geological Horizons.	Strata.	New Jersey Localities.
Matawan.		Cliffwood
Upper Potomac (Amboy Clays).	Island Series.	Morgans (?)
	Albirupean Series	South Amboy Perth Amboy. Sayreville Woodbridge.
?	("Iron Ore Series"?)	
Middle Potomac.	Acquia Creek Series.	Not known in New Jersey.
Basal Potomac.	Mount Vernon Series.	
	Rappahannock Series.	
	James River Series.	

Whether or not all of Dr. Ward's conclusions will stand, appears to me, will depend upon future investigation. Thus far I have failed to find the equivalent of the Island Series on the mainland of New Jersey in the region where it should theoretically occur, nor have the ferruginous concretions and fragments, by which the series is characterized on the islands, been found there, and the fact of their absence on the mainland, and their presence on the islands only in connection with the terminal moraine, has led me to think that they are not characteristic of the series except as representing fragments of clay strata which were originally in a plastic condition but which have become hardened by oxidation after having been torn up and made part of the morainal material. This view is further strengthened by the fact that these concretions and fragments may be found in the moraine in every stage of development from masses of soft clay with only a thin shell of limonite on the outside to those which are hardened throughout. Many of the hardest fragments also exhibit beautifully defined planes of shearing or slipping, evidently accomplished before the process of hardening had been completed. In several localities, notably at Glen Cove, Long Island, and at Gay Head, Martha's Vineyard, the shaly fragments and concretions occur in the Cretaceous clay strata, but these strata are greatly contorted and have been subjected to similar conditions to those which have wrought the changes noted in the mixed morainal material. The disturbance of the strata would naturally expose them to the same oxidizing influences and would cause portions of them to be converted into hardened seams or assist in the formation of concretions. So that until we find the strata upon the mainland with such hardened seams, fragments or concretions in place and containing representatives of the same flora, the most reasonable explanation of their occurrence throughout the morainal region of the islands would seem to be that it is due to oxidation caused by the disturbance wrought there by glacial action.

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[1] The Potomac Formation, 15th *Ann. Rept. U. S. Geol. Surv.*, 335, 336.

[2] The Flora of the Amboy Clays, *Monog. U. S. Geol. Surv.*, XXVI.

[3] The Cretaceous Clay Marl Exposure at Cliffwood, N. J., *Trans N. Y. Acad. Sci.*, XVI (1897), 124–136.

Cretaceous Plants of Staten Island.

In the following list Nos. 4, 5, 8, 9, 10, 11, 12, 14, 15 and 16 have not before been reported from Staten Island, and No. 12 represents a species here described for the first time.

1. **Moriconia cyclotoxon** Deb. & Ett.

(Plate XXXVII, Fig. 8.)

Moriconia cyclotoxon Deb. & Ett., Urwelt. Acrob. Kreidegeb. Aachen und Maestricht, p. 59 (239), Pl. VII, Figs. 23–27.

Locality: Prince's Bay, Staten Island.

2. **Thinnfeldia Lesquereuxiana** HEER.

(Plate XXXVI, Fig. 6.)

Thinnfeldia Lesquereuxiana Heer, Fl. Foss. Arct., Vol. VI, Abth. II, p. 37, Pl. XLIV, Figs. 9, 10; Pl. XLVI, Figs. 1–11, 12a and b.

Locality: Tottenville, Staten Island.

3. **Populus Harkeriana** LESQ. (?)

(Plate XXXVI, Fig. 8.)

Populus Harkeriana Lesq., Fl. Dak. Gr., p. 44, Pl. XLVI, Fig. 4.

Although somewhat imperfect in outline, this specimen appears to agree in all essential particulars with this species and seems to warrant at least a provisional reference to it.

Locality: Tottenville, Staten Island.

4. **Salix inæqualis** NEWB.

(Plate XXXVIII, Fig. 4a.)

Salix inæqualis Newb., Fl. Amboy Clays, p. 67, Pl. XVI, Figs. 1, 4, 6; Pl. XVII, Figs. 2–7.

Locality: Arrochar, Staten Island.

5. **Myrica longa** HEER.

(Plate XXXVIII, Fig. 6.)

Proteoides longus Heer, Fl. Foss. Arct. Vol. III (Kreidefl.), p. 110, Pl. XXIX, Fig. 8b; Pl. XXXI, Figs. 4, 5.

Myrica longa Heer, *ibid.*, Vol. VI, Abth. II, p. 65, Pl. XVIII, Fig. 9b; Pl. XXIX, Figs. 15–17; Pl. XXXIII, Fig. 10; Pl. XLI, Fig. 4d.

Locality: Arrochar, Staten Island.

6. **Ficus Woolsoni** NEWB. (?)

(Plate XXXVII, Fig. 9.)

Ficus Woolsoni Newb., Fl. Amboy Clays, p. 70, Pl. XX, Fig. 3; Pl. XXIII, Figs. 1–6.

It is with considerable hesitation that I have provisionally referred this fragmentary specimen to this species. Fig. 6 of Plate XXIII, seems, however, to approach it quite closely. A similar specimen was also found in the clay at Kreischerville, which I referred provisionally to the same species (Trans. N. Y. Acad. Sci., Vol. XII (1892), p. 33, Pl. II, Fig. 1) and there can be hardly any doubt that our two specimens represent one and the same species.

Locality: Tottenville, Staten Island.

7. **Protæoides daphnogenoides** HEER.

(Plate XXXVI, Figs. 1–3.)

Protæoides daphnogenoides Heer, Phyl. Crét. Nebraska, p. 17 Pl. IV, Figs. 9, 10.

This species was identified in the Amboy clays of New Jersey by Newberry and whether his specimens are correctly referred or not, there can be no doubt of the identity of our specimens with those from New Jersey. (See Fl. Amboy Clays, Pl. XXXII, Figs. 11, 13, 14.)

Locality: Tottenville, Staten Island.

8. **Myrsine elongata** NEWB.

(Plate XXXVIII, Figs. 3, 4b and c.)

Myrsine elongata Newb., Fl. Amboy Clays, p. 122, Pl. XXII, Figs. 1–3.

Locality: Arrochar, Staten Island.

9. **Andromeda Parlatorii** HEER.

(Plate XXXVII, Fig. 7.)

Andromeda Parlatorii Heer, Phyl. Crét. Nebraska, p. 18, Pl. I, Fig. 5.

For purposes of comparison the specimens figured by Newberry (Fl. Amboy Clays, Pl. XXXI, Figs. 1–7; Pl. XXXIII, Figs. 1, 2, 4, 5) are better than the type specimen figured by

Heer. This is particularly the case in regard to Figs. 2 and 4, Pl. XXXI, above quoted.

Locality: Tottenville, Staten Island.

10. **Hedera** sp.?

(Plate XXXVIII, Fig. 5.)

This specimen is too fragmentary for more than a generic reference. It may possibly be a small specimen of *H. primordialis* Sap., as depicted by Newberry in the Flora of the Amboy Clays, Pl. XXXVII, Figs. 1–7.

Locality: Tottenville, Staten Island.

11. **Aralia rotundiloba** NEWB. (?)

(Plate XXXVIII, Fig. 2.)

Aralia rotundiloba Newb., Fl. Amboy Clays, p. 118, Pl. XXVIII, Fig. 5; Pl. XXXVI, Fig. 9.

The obliteration of the lobing in this specimen renders accurate determination impossible. It may, perhaps, also be compared with *Cissites ingens* Lesq. (Fl. Dak. Gr., Pl. XIX, Figs. 2, 2a), or with *C. formosus* Heer, as identified by Newberry. (Fl. Amboy Clays, Pl. XLVII, Figs. 1–8.)

Locality: Tottenville, Staten Island.

12. **Pistacia Aquehongensis** n. sp.

(Plate XXXVI, Fig. 5.)

Leaf entire, linear-elliptical in outline, about ¾ in. long by ¼ in. wide; nervation finely and uniformly pinnate, secondaries leaving the midrib at a somewhat obtuse angle, closely parallel and connected near the margin by cross nervation in a series of angles.

The specific name refers to "Aquehonga," the Indian name for Staten Island.

This leaf is closely similar to *P. aquensis* Sap. (Ann. Sci. Nat., Ser. V. Bot., Vol. XVIII (1873), p. 105, Pl. XV, Figs. 1–24), which, however, is a Tertiary species.

Locality: Tottenville, Staten Island.

13. **Sapindus Morrisoni** Lesq.

(Plate XXXVI, Fig. 4.)

Sapindus Morrisoni Lesq. Cret. & Tert. Fl., p. 83, Pl. XVI, Figs. 1, 2.

Locality: Prince's Bay, Staten Island.

14. **Sterculia Snowii** Lesq. (?)

(Plate XXXVII, Fig. 4.)

Sterculia Snowii Lesq. Fl. Dak. Gr., p. 183, Pl. XXX, Fig. 5; Pl. XXXI, Figs. 2, 3; Pl. XXXII; Pl. XXXIII, Figs. 1–4.

This specimen is too fragmentary for more than provisional reference.

Locality: Tottenville, Staten Island.

15. **Sterculia** sp.?

(Plate XXXVII, Fig. 5.)

Locality: Tottenville, Staten Island.

16. **Pterospermites modestus** Lesq.

(Plate XXXVII, Fig. 6.)

Pterospermites modestus Lesq. Fl. Dak. Gr., p. 186, Pl. LVIII, Fig. 5.

Locality: Tottenville, Staten Island.

17. **Magnolia longifolia** Newb. (?)

(Plate XXXVII, Fig. 3.)

Magnolia longifolia Newb. Fl. Amboy Clays, p. 76, Pl. LV, Figs. 3, 5; Pl. LVI, Figs. 1–4.

This specimen is evidently a fragment of a large leaf, with the nervation of *Magnolia*, and its provisional reference to one of the Amboy clay species seems to be justifiable.

Locality: Tottenville, Staten Island.

18. **Dewalquea Groenlandica** HEER. (?)

(Plate XXXVI, Fig. 7.)

Dewalquea Groenlandica Heer. Fl. Foss. Arct., Vol. VI, Abth. II, p. 87, Pl. XXIX, Figs. 18, 19; Pl. XLII, Figs. 5, 6; Pl. XLIV, Fig. 11; *ibid.*, Vol. VII, p. 37, Pl. LXII, Figs. 5, 6.

The reference of our specimen to this species is questionable. Amongst all of Heer's figures the only one with which it can be satisfactorily compared is Fig. 6, Pl. LXII, above quoted. Nevertheless, as our specimen is apparently identical with those provisionally referred to the species in the Flora of the Amboy Clays (p. 129, Pl. XLI, Figs. 2, 3, 12), I have thought it best to retain the name.

Locality: Tottenville, Staten Island.

19. **Tricalycites papyraceus** Newb.

(Pl. XXXVII, Figs. 1, 2.)

Tricalycites papyraceus Newb., Fl. Amboy Clays, p. 132, Pl. XLVI, Figs. 30–38.

Locality: Tottenville, Staten Island.

20. **Rhizomorphs.**

(Pl. XXXVIII, Fig. 1.)

I use the term Rhizomorph in the same sense as it was originally used by the late Dr. J. I. Northrop, in describing similar cylindrical structures in the coral rocks on the island of Nassau. (Notes on the Geology of the Bahamas, *Trans. N. Y. Acad. Sci.*, Vol. X (1890), p. 16.) It has no connection with the fungus genus *Rhizomorpha*.

Amongst the commonest of the fossil remains found in the hardened clay nodules in the drift at Tottenville are those which I have included under the comprehensive name of Rhizomorphs. They usually consist of limonite tubes, concretionary in structure, sometimes hollow, sometimes containing lignite or pyrite. Occasionally the lignite has no casing of limonite around it.

They invariably extend through the rock at, or nearly at, right angles to the plane of stratification and are either straight or sparingly branched. Where the ends appear on the surfaces of the rock these give rise to little pits, usually encircled by the rims of the limonite tubes. On breaking one of these nodules open the structure and arrangement of the remains may be observed.

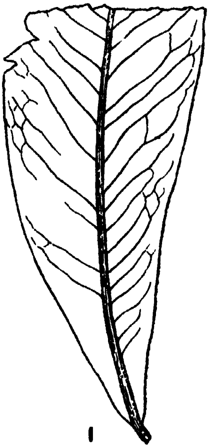
I have never seen any fossils in the Cretaceous clays which are comparable to them, but roots of living plants which have found their way down into ferruginous clays and sands often produce very much the appearance of our specimens, and I am inclined to think that these rhizomorphs represent the lignified remains of former living roots, which were retained in their original positions after the clay had been torn up and transported. During the subsequent hardening of the clay and the oxidation of its contents, iron-bearing water followed along the roots, gradually depositing a tube of limonite, while the vegetable· tissue was either destroyed or converted into lignite. From this point of view our rhizomorphs would represent post-Cretaceous preglacial vegetation.

PLATE XXXVI.

PLATE XXXVI.

Cretaceous Plants from Staten Island.

		PAGE.
Figs. 1–3.	**Protæoides daphnogenoides** Heer. Tottenville	420
Fig. 4.	**Sapindus Morrisoni** Lesq. Princes Bay	422
Fig. 5.	**Pistacia Aquehongensis** Hollick. Tottenville	421
Fig. 6.	**Thinnfeldia Lesquereuxiana** Heer. Tottenville	419
Fig. 7.	**Dewalquea Grönlandica** Heer (?) Tottenville	423
Fig. 8.	**Populus Harkeriana** Lesq. (?) Tottenville	419



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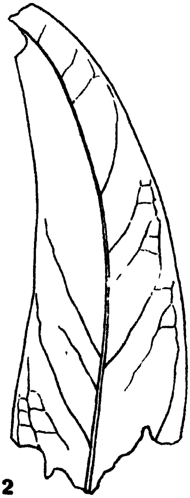

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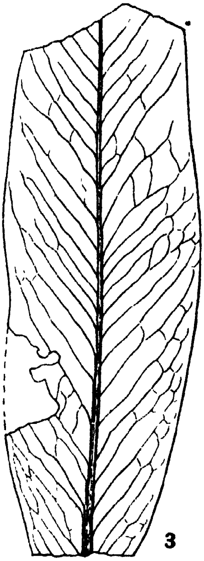

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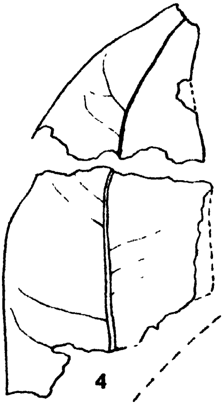

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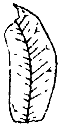

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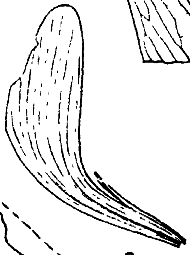

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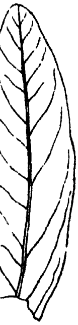

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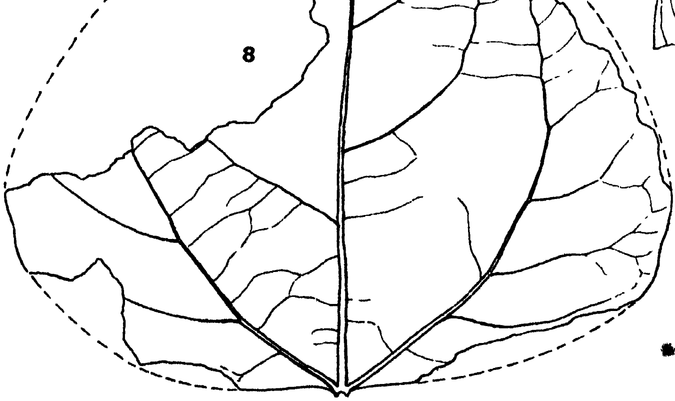

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PLATE XXXVII.

PLATE XXXVII.

Cretaceous Plants from Staten Island.

		PAGE
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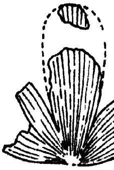
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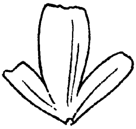
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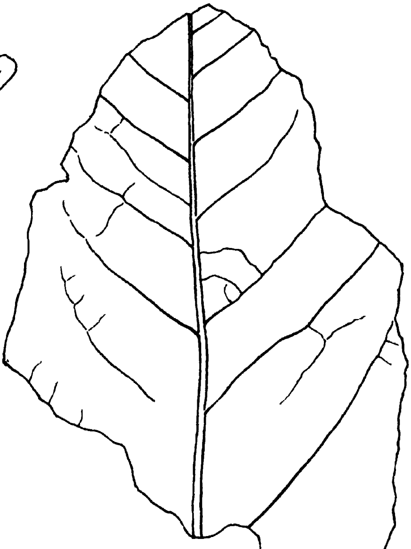
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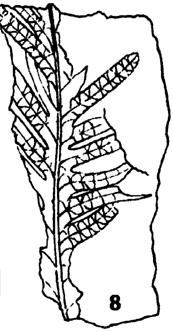
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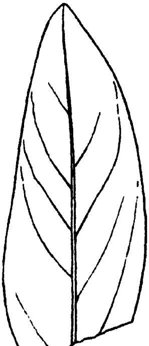
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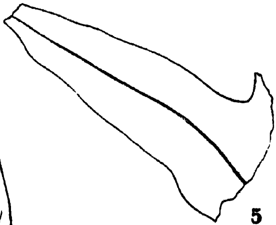
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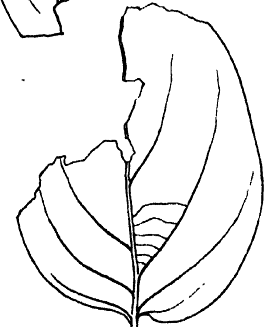
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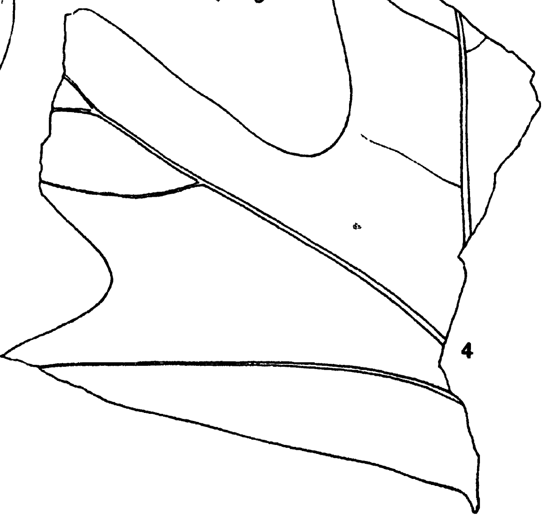
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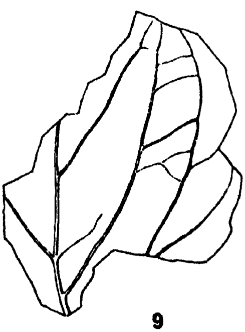
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PLATE XXXVIII.

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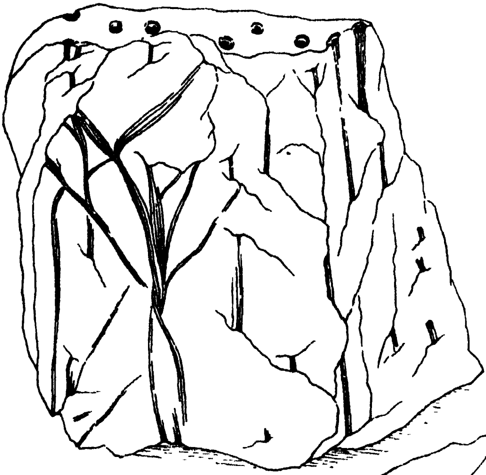

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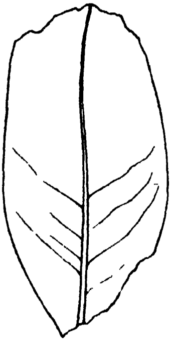

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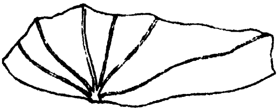

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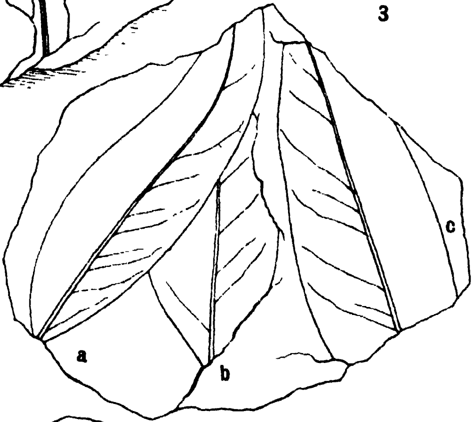

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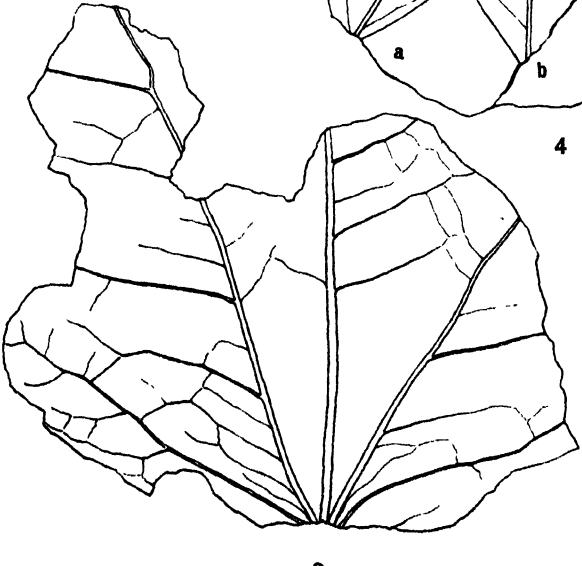

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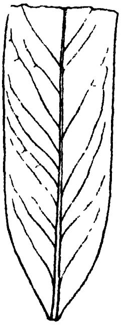

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[ANNALS N. Y. ACAD. SCI., XI, No. 21, pp. 431 to 441, December 17, 1898.]

THE LATTER PART OF LUCRETIUS, AND EPICURUS περὶ μετεώρων.

E. G. SIHLER.

(Read March 28, 1898)

THE charm of Lucretius is perennial. The source of it, however, is rather complex. That his work is the foremost didactic poem of antiquity is admitted. That his manipulation of the possibilities of the Latin tongue stamps it, as Teuffel says, as the production "Eines Sprachgewaltigen" few would gainsay. That his *exordia* and many of his digressions really are meant by the *lumina* of Cicero's judgment in his letter to his brother Quintus (2, 11) seems most probable. And still stronger than these is the tremendous earnestness of the man. We have a distinguished Epicurean in the generation after L., Horace of Venusia. To him, too, we may trace that blending of morals, of quasi-religious conviction and strictly philosophical tenets, which constituted adherence to the one or the other of the two most prominent sects of the day: the Epicurean and the Stoic. These conditions Horace evidences most frankly in his earlier writings, *e. g.*, in the Iter Brundusinum, I, Sat. 5, 97.

> dein Gnatia lymphis
> Iratis extructa dedit risusque iocosque,
> Dum flamma sine tura liquiscere limine sacro
> Persuadere cupit. Credat Judaeus Apella
> Non ego: namque deos didici securum agere ævum,
> Nec, siquid miri faciat natura, deos id
> Tristes ex alto caeli demittere tecto.

The vanity of concern for the utter extinction implied in the mortality of the soul is iterated in his Odes, as is the vanity of all human passions; the good-natured banter of criticism of Stoic exaggeration comes naturally from an Epicurean; but the fearless and uncompromising attack on the Etruscan religion of his country is not sounded by the pensioner of Maecenas, and the poet who composed for the princeps the Carmen Saeculare and supported distinctly the social and religious reforms so dear to Augustus (recorded too as the latter's dearest aspirations in the Monumentum Ancyranum) could not well make a propaganda—for Epicureanism. It is different with Lucretius. His tremendous earnestness is coupled with a humility and reverence for the person and doctrine of Epicurus which I need not substantiate here in detail, I, 66–79, III, 1 sqq, and particularly III, 1042

> ipse Epicurus obit decurso lumine vitæ
> qui genus humanum ingenio superavit et omnis
> restincsit, stellas exortus ut ætherius sol . . .

and the much quoted lines V, 8, sq.

> deus ille fuit, deus, inclyte Memmi
> qui princeps vitæ rationem invenit eam quæ
> nunc appellatur sapientia . . .

As to the Greek sources of Lucretius: was there anything beside Epicurus himself? If so, what? If not, which writings of E.? Then too: did he base it all on the 37 bb. of E. *περὶ φύσεως*? The exhaustive grouping of every shred of Epicurean doctrine by H. Usener, of Bonn, in his Epicurea, Leipzig, 1887, with the critical edition of the text of book X, of Diogenes Laertius is a monument of erudition . . . still, inasmuch as Epicurus' doctrine is stated there with very great conciseness as a summary digest for the conning of confirmed disciples and not with explicit clearness nor argumentative breadth, the temptation has always been great for students of the subject to make Epicurus' letter to Herodotus a "source" of L.

The exact mode in which Lucretius used the main work the 37 bb. *περὶ φύσεως* will probably never be known, inasmuch as, although there were three complete copies of Ep. *περὶ φύσεως* in the villa of Piso at Herculaneum, the deciphered fragments from the carbonized rolls are entirely too scanty to permit inferences; if Philodemus, a second-rate writer, was represented with his endless volumina in that Epicurean library, are we to believe that a Lucretius was content with a perusal of anything short of the great dogmatic work of the master? It is not likely. This, too, is made more probable by the substantial elements of controversial analysis or censure directed against other schools, and particularly against the Stoics, although the latter are never mentioned by name throughout the work of Lucretius. These controversial elements certainly were not in themselves attractive to such Roman readers as were to be made proselytes of the sect. Therefore, I do not see how the parallels between the letter to Herodotus and between Lucretius, elaborated by *Ivo Bruns* in his Lucrezstudien, Freiburg, Tuebingen, 1884, prove anything in this respect. Nor am I convinced of the main thesis of Bruns, that Lucretius, in the course of the elaboration of his work, determined quietly to omit or remove the treatment of the theory of cognition, *τὸ κανονικόν*, of the system of Epicurus.

Why should we assume that the treatment of the *Κανὼν* was an essential part of the 37 bb *περὶ φύσεως* when, as we see in Diogenes L. X., 27, there was a distinct volume *περὶ κριτηρίου ἢ Κανών*. . . .

Lucretius essayed to show that this physical theory truly emancipated the souls of men from fear of death and from all the terrors with which the traditional mythology had invested the Inferno, that it secured that peace of soul which in the Epicurean conception is essentially negative, freedom from all the passions whether involved in the persuit of wealth, of sexual indulgence [hence the appendix of book IV in L.,] or of political preëminence. This is "purgare pectora" L. VI, 24. Now books I–IV substantially present in sequence what Epicurus called *ἡ γνήσιος φυσιολογία*: [letter to Pythocles, Diog. L. 10, 85]. But books V and VI of L. are apt to make at first the impression of a mass of unrelated or ill-related matter. As for book V the very exordium 55 sqq. states distinctly a complex theme: the creation of organic beings, persistence of created types, essentially physical nature of mind: deception of man by visions. My next theme [rationis ordo]: this organic universe is perish-able [Diog. L. 10, 74 *φθαρτοὶ οἱ κόσμοι*]. Earth, sky, sea, stars, sun and moon established by that association of matter, creation of living beings out of the earth [primitive civilization], origin of speech, religion, absence of conscious purpose in the movement of heavenly bodies, no teleology: celestial mechanics directed by no divine providence.

These themes are actually found in the book, although in a somewhat different order. Beginning with V. 509 sqq. we begin to notice that characteristic mark of Epicurus' treatment of "*τὰ μετέωρα*," viz., the advancement of two or more theories to explain phenomena so radically different from the absolute positivism of the atomistic physical system proper, of boks I.–IV. But it may be more instructive to present at first tables showing the themes and the sequence of themes in Epicurus and in Lucretius.

EPICURUS TO PYTHOCLES.

Diog. Laert. X. 85 sqq.
Sun, moon and "other stars"
Size of sun.
Decline and filling of the moon.
Face in moon.
Eclipses.
τάξις περιόδου.
Length of night and day.
Clouds.
Rain.
Thunder.
Lightning.
Thunderbolt.
Waterspouts.
Earthquakes.
Winds.
Hail.
Snow.
Dew.
Hoarfrost.
Ice.

LUCRETIUS V.

509. Motion of stars.
564. Size of Sun.
Heat of Sun.
619. Sun's mutation of course in the year.
650. Night,
656. Periodicity of sunrise.
680. Correlation of day and night in length.
705. moon's phases.
751. Eclipses.
(771–779 resumé.)

BOOK VI.

96. Thunder.
219. Lightning: optical phenomena.
379. Lightning: destructive phenomena.
451. Clouds.
495. Rain.

Rainbow.
Halo of moon.
Comets.
Slower movements of some stars.
Meteors.
Seasons. (?)

527. Snow, hail, hoarfrost, ice. (A few lines only.)
535. Earthquakes.
639. Etna.
713. Nile. (explanation of summer-rise.)
738. Exhalation of Avernus.
840. Puzzling changes of temperature.
906–1082. Magnet.
1090. Epidemics in general.
1138. The plague at Athens. 430–429. (Paraphrase of Thucyd. II 47–55.)

The most striking thing in the letter to Pythocles is this: The interest of Epicurus in the explanation of these phenomena is not a scientific or even a positive one: it is mainly negative; to furnish *natural* explanations, an assortment of two or three or four or even more, sometimes without much, if any, indication which to prefer as long as the idea of any divine will or agency as a factor was utterly cancelled from the problem; cf., also, in letter to Herodotus § 76 *καὶ μὴν ἐν τοῖς μετεώροις φορὰν καὶ τροπὴν καὶ ἔκλειψιν καὶ ἀνατολὴν καὶ δύσιν καὶ τὰ σύστοιχα τούτοις μήτε λειτουργοῦντός τινος νομίζειν δεῖ γίνεσθαι καὶ διατάττοντος ἢ διατάξαντος καὶ ἅμα τὴν πᾶσαν μακαριότητα ἔχοντος μετὰ ἀφθαρσίας* . . . and so in the letter to Pythocles § 97 of the course of the sun . . . *καὶ ἡ θεία φύσις πρὸς ταῦτα μηδαμῇ προσαγέσθω ἀλλὰ ἀλειτούργητος διατηρείσθω καὶ ἐν τῇ πάσῃ μακαριότητι, ὡς εἰ τοῦτο μὴ πραχθήσεται ἅπασα ἡ περὶ τῶν μετεώρων αἰτιολογία ματαία ἔσται.* And further recurring to the element of supernatural cause 87–, "*ἐπὶ τὸν μῦθον καταρρεῖ.*" And § 115, speaking of other possible modes of explaining meteora: "*καὶ ἄλλοι δὲ τρόποι εἰς τὸ τοῦτο τελέσαι ἀμύθητοί εἰσιν.*"

When we turn away from this general negative bias of this summary *μετεωρολογία* we are met by a curious and puzzling characteristic.

These phenomena, according to Epicurus, according to their very nature, are unattainable to our positive knowledge; many explanations are possible for each of them as a rule, one is as good as the other; their knowledge is a mere inferior corollary to the system of atomism proper, *ἡ γνήσιος φυσιολογία* (Diog. L. 10. 85). The aim of this *αἰτιολογία* is not scientific precision, nor the satisfaction of the craving for accurate knowledge; no, here too it is (§85) *ἀταραξία*; these themes belong to an entirely different category from the (§ 86) *τῶν ἄλλων φυσικῶν προβλημάτων κάθαρσις*, *e. g.*, that the universe is material and intangible (*ἀναφής*) as to its fundamental substance (*i. e.*, as to the atoms), and that the atoms are the material principle, principles which are in *absolute* harmony with phenomena; not so, however, with *μετέωρα*; *,ἀλλὰ ταῦτά γε πλεοναχὴν ἔχει καὶ τῆς γενέσεως αἰτίαν καὶ τῆς οὐσίας ταῖς αἰσθήσεσι σύμφωνον κατηγορίαν.*

The main point is not to adopt and persist in any *one* explanation, but give equal authority to them all as long as none of them is in hisharmony with parallel or analogous processes from the spheres of our actual empirical perception and observation (*ἐναργήματα* § 93)...

In one passage § 94 he refers to the adoption of the single or exclusive as "being smitten" with it—cf. § 98 (*καταγαπᾶν*) as a folly of him who knows not the (§ 113) limits of human survey. And so—a brief illustration must suffice—*e. g.*, he gives *four* explanations of the changes of sun and moon, and speaks with scorn of the computations of professional astronomers as (§ 93) *τὰς ᾽ανδραπωδώδεις ᾽αστρολόγων τεχνιτείας*. . . . of the decline and increase of the moon he offers not less than *six*; explanations, of clouds (§ 99), *four*; of rain, *four*; of thunder, *five* (§ 100); of lightning § 101–102, *seven*; of earthquakes, *three*; with a fourth collective which recurs frequently. It would be mere iteration to go through the whole list.

This easy eclectic attitude towards the real solution of these phenomena, this absolutely unscientific, nay childish, position as over against exact science, naturally brought Epicurus and his school into very glaring contrast as over against the positive attainments of the Peripatetic and Stoic schools.

And so this particular matter well illustrates the attitude of Epicurus and his school to technical culture or towards the cultivation of technical knowledge. Usener has collected the passages: Epicurea, p. 170, sqq. Cf. particularly Diog. 10, 6 *παιδείαν δὲ πᾶσαν, μακάριε, φεῦγε, τἀκάτιον 'αράμενος* and Quintil. 12, 2, 24, "fugere omnem disciplinam." But, we are all told, there are doubts as to the genuineness of the letter to Pythocles, so that Usener, while critically editing it with the other two letters, brackets the title. This is due to a notice of Philodemus in the Herculanean papyri, 2d collation, Tom. 1, fol. 152, with Usener's supplements, p. 34.

> "ὑποψ[ία]ν τιν[ὰ] [λα]μβάν[ει]ν 'ως περὶ τινῶν
> ʽεπίστολ[ῶν] καὶ τῆς [πρὸς Πυθ]οκλέα π[ε]ρὶ[με]τεώρων
> ʼεπιτομῆς καὶ τοῦ περὶ 'αρετῶν κτἑ . . ."

The notice of Philodemus, who was a close contemporary of Lucretius and intimate friend of Calpurnius Piso, really is, in the first place, a prima facie proof that this piece of Epicurean writing *existed in his day* and had a place among the works of Epicurus. Further, the summaries must have (like the *κυρίαι δόξαι*) enjoyed a much greater vogue than the bulky works of Epicurus; they were evidently studied and passed on from generation to generation in a school in which the *ipse dixit* of the master was zealously maintained as the standard of true doctrine. It is natural, on the other hand, and most probable that a man of real attainments and wide knowledge like Philodemus had little love for this weakling among the intellectual progeny of the son of Neocles, and would have been glad to have it neglected or cast aside as a bastard.

The genuine and profound indifference of Epicurus towards this entire sphere of themes I need not emphasize again; it is unfair to demand (as Usener does) more apt arrangement and fitness in the succession of themes—or what succession of themes would Usener postulate? The strongest argument for the genuineness of this second-rate product of Epicurus, however, is afforded by the parallel of Lucretius' themes.

He is not (as Epicurus did not) desiring to write an exhaustive or systematic treatise on physical phenomena both normal and abnormal ; at the first reading of the greater part of Book V and all of Book VI one cannot suppress a feeling that system is cast to the winds and to miss that rigid, comparatively speaking, that rigid sequence of treatment which is so unmistakable in the general unfolding of Epicurean doctrine in Books I–IV. Cf. Munro's commentary on Lucretius V, 533. And with Epicurus' incessant railing against the postulate of *one* explanation (*τὸν μοναχῇ τρόπον*, § 95 l. c. and § 113 *τὸ δὲ μίαν αἰτίαν τούτων ᾿αποδιδόναι, πλεοναχῶς τῶν φαινομένων ᾿εκκαλουμένων, μανικόν ἐστι*). Cf. Lucretius V, 620, " *non* inquam, *simplex* his rebus reddita causast."

" 729 [of two different astronomical theories]
"proinde quasi id fieri nequeat quod pugnat uterque
"aut minus hoc illo sit cur amplectier ausis."

And 751.

Solis item quoque defectus lunaeque latebras
pluribus e causis fieri tibi *posse* putandumst.

And so again in book VI, 703 sqq., the theory of *αἰτιολογία* is advanced even more clearly :

" Sunt aliquot quoque res quarum *unam* dicere *causam* non satis est, *verum pluris, unde una tamen sit*; as f. e. when you see the dead body of a man lying at *a distance* [*i. e.*, precluding a close and direct inspection on our part] ; there it behooves us to exhaust the entire range of contingencies through which a man may perish ; although we cannot, at that distance, prove any particular single one : the sword, or frost, or disease, or poison. And so we find the same plurality of explanation in Lucretius : positive and exclusive asseverations in this sphere are impossible.

V 526 nam quid in hoc mundo sit eorum *ponere certum difficile est ;* sed quid possit fiatque per omne [das All].

in variis mundis variā ratione creatis
id doceo *pluris*que sequor *disponere* causas, etc. . .

e. g., V, 509 sqq. of the motion of the stars *three* conjectural explanations, with two alternatives for the third; for the light of the moon 575 *two;* the periodical mutations in the sun's course 614 sqq. *two;* the problem of night (650), *two;* the correlation of day and night 680 sqq. *three;* moon's phases 705 sqq. *three;* eclipses 750 sqq. *two.*

Thunder VI, 96, *nine* explanations; lightning (246), *four;* waterspouts (423), *two;* clouds (451), *five;* rain (495), *four;* earthquakes (535), *four;* rise of Nile (712), *four.*

It is a matter of some interest, philologically, to survey the range of expression in which each writer presents the modality of possibility of alternative conjecture; in Diog. L. 10, 93; *᾿ενδέχεται. . . ὁμοίως. . . ἢ καὶ. . . ἢ καὶ—*; 94 *καὶ ὁμοίως, . . ἔτι δὲ καί. . . ἔτι τε ᾿ενδέχεται. . . ᾿ενδέχεται δὲ. . .* in 95; *δύναται καί. . . . καί. . .* in 107; *᾿ενδέχεται. . . γίνοιτο ἂν. . . ᾿αποτέλεσιν ἄν λαμβάνοι. . .* in 111 *ἢτοι. . . ἢτοι ἢ.*—in 112; *οὐ μόνον. . . ᾿αλλὰ καί. . . ἢ. . .—καὶ κατ ἄλλους δὲ πλείονας τρόπους δύναται.* With this compare Lucretius V, 515 sqq. Aut. . . est etiam quoque uti possit. . .; 375 sq. sive. . . . sive. . . .; 637 fit quoque ut; 651 Aut. . . aut. . . quia; also 658, 660, 682, 697; aut etiam quia 701; potest 705, est etiam quare 715; and 731 sqq. cur nequeat. . . , difficilest ratione docere. . . 753 sqq. cur luna queat. . . non posse putetur. . . 762, cur terra queat. . . 765 aliut nequeat. . . and in VI, 97 propterea quia. . . 108 etiam. . . 116 fit quoque. . . ut; 121 hoc etiam pacto. . . videntur; 132 est etiam ratio. . .; 137 fit quoque ut. . . 142 sunt quoque 156 denique. . . 160 item.—295 est etiam cum.

It cannot be my aim to enter into the detail, much less into the scientific merits, of these explanations; it is curious and noteworthy that Seneca in book VI of his *naturales quaestiones* dealing with the problem of earthquakes [a theme suggested by the great earthquake of 63 A. D., from which Pompei and all the gulf of Naples suffered], in reviewing the extant theories on earthquakes, while quoting the Epicurean Metrodorus c. 19; and Epicurus himself does not mention Lucretius, with whom he was familiar. Now Seneca puts Epicurus 6, 20 in the category of those "qui *omnia ista quae retuli* in causa esse dixerunt aut *ex his plura.* And particularly VI, 20, § 5 is so strong a confirmation of the letter to Pythocles that it seems pertinent to give part of it entire: omnes istas posse esse causas Epicurus ait pluresque alias temptat, et *alios*, qui *aliquid unum* ex iis esse adfirmaverunt, *corripit*, cum sit arduum de his quae coniectura sequenda sunt, aliquid certi promittere." And so the version of Seneca contains the following words or phrases of alternative conjectural statement: potest, potest, fortasse enim, fortasse, fortasse, fortasse, fortasse, fortasse . . . et inde aut, aut.

But Lucretius has further themes which hardly come within the sphere of *μετέωρα*, Etna, Nile, exhalation of Avernus, odd changes of temperature in a certain spring, the Magnet, Epidemics, the Plague at Athens. True, but his fundamental interest is that of ad Pythoclem § 104: *μόνον ὁ μῦθος ’απέστω, ’απέσται δὲ, εάν τις καλῶς τοῖς φαινομένοις ’ακολουθῶν περὶ τῶν ’αφανῶν σημειῶται.* The absolute elimination of divinity as factor or efficient cause, § 113 and 116, ‘learn this by heart,’ my dear Pythocles; for the sequence is stated as a two-fold one: *κατὰ πολύ τε γὰρ τοῦ μύθου ’εκβήσῃ καὶ τὰ ὁμογενῆ τούτοις συνορᾶν δυνήσῃ.* And so we see Lucretius engaged in elaborate and ambitious efforts to apply the abstract and fundamental doctrines of atomism, *e. g.*, in dealing with Etna, 647 sqq., with Avernus and its reputed exhalations, 769, 790 sqq., w. the magnet, 906 sqq., where the preliminary elaboration of first principles is carried on with such fulness that the poet apologizes:

919. et minimum longis ambagibus est adeundum and
1081. nec tibi tam longis opus est ambagibus usquam
nec me tam multam hic operam consumere par est . . .

and while it is his ambitious attempt to apply fixed principles (cf. Diog. L. 10, 116, "*τὴν τῶν ’αρχῶν καὶ ’απειρίας καὶ τῶν συγγενῶν τούτοις θεωρίαν*)" to definite physical problems which swelled the theme of the *Magnet* to the bulky total of 184 lines (905–1089), let us glance at the theme of Thunder and Lightning in the earlier part of book VI, 96–379, a little less than 300 lines . . . and then follows the fervid attack on the formulæ of the Etruscan ritual and the folly of ascribing these manifestations to Jupiter;

which uprooting of popular fear of the gods with its interdependence with the fear of death is really the chief motive and the very essence of this unique poem . . . the practical. moral interest of emancipating the soul vastly predominates over the didactic or speculative interest.

But the limits of the *liber*, the mechanical necessity even of limitation, so instructively elaborated by Th. Birt in his "Das Antike Buchwesen," 1882, put their constraint upon the poet; so that alongside of these disproportionate elaborations of particular themes as just noted we find, *e. g.*, VI, 527 sqq. snow, winds, hail, hoarfrost, ice merely summarily mentioned, and turned over to the reader's application of first principles. We must not incline, however, to the assumption that this apparent miscellany of physical and meteorological themes and problems in Lucretius V and VI was a mere appendix, or second-thought supplement of the work proper; for in the very first detailed announcement of his chief themes, in I, 127, this entire matter is even placed first in order:

> Qua propter bene cum *superis de rebus* habenda
> nobis est ratio, solis lunæque meatus
> qua fiant ratione. . .

In conclusion we ask were the *μετέωρα* an essential part of the 37 bb. *περὶ φύσεως*? It seems impossible to prove that the letter to Herodotus, § 35, 83, in Diog. L., X, is a true, *i. e.*, an even and truly proportioned summary of the entire range of the great work of 37 bb., the brief reference to *μετέωρα* in § 76 is too slender for elaborate or positive inferences. In the list of E's works Diog. L., 10, 27, of some forty-nine titles with 89 *volumina* are recorded as *τὰ βέλτιστα* out of the total of 300 *κύλινδροι* with the exception of *περὶ νότων δόξαι* there is no title specifically bearing on the subject of *μετέωρα.*

New York University, 1898.

[ANNALS N. Y. ACAD. SCI., XI, No. 22, pp. 443 to 499, January 18, 1899.]

RECORDS OF MEETINGS

OF THE

NEW YORK
ACADEMY OF SCIENCES.

JANUARY, 1898, TO DECEMBER, 1898.

RICHARD E. DODGE,

Recording Secretary.

[ANNALS N. Y. ACAD. SCI., XI, No. 22, pp. 445 to 499, January 18, 1899.]

RECORDS OF MEETINGS

OF THE

NEW YORK ACADEMY OF SCIENCES.

January, 1898, to December, 1898.

RICHARD E. DODGE, *Recording Secretary.*

REGULAR BUSINESS MEETING.

JANUARY 3, 1898.

Academy met with President Stevenson in the chair. The minutes of the last meeting were read and approved. The Secretary presented for election as Resident Members the names of the following candidates which had been duly approved by the Council.

RESIDENT MEMBERS ELECTED.

F. W. Devoe, 101 Fulton street.
W. G. Dewitt, 88 Nassau street.
E. I. Haines, New Rochelle, N. Y.
Michel M. LeBrun, 8 Mountain avenue, Montclair, N. J.
Charles S. Schultz, Hoboken, N. J.
S. L. H. Ward, 67 Wall street.

The Secretary was authorized to cast a ballot for the names read, and all were declared elected.

The section of Astronomy and Physics then organized.

J. F. KEMP,
Secretary.

SECTION OF ASTRONOMY AND PHYSICS.

JANUARY 3, 1898.

Mr. Dudley in the chair, eighteen members and guests present. W. Hallock was appointed Secretary, *pro tem.* Minutes of last meeting read and approved.

The first paper was by **H. Jacoby,** entitled PHOTOGRAPHIC RESEARCHES NEAR THE NORTH POLE OF THE HEAVENS. Professor Jacoby explained how the "trail plates" are taken with stationary telescope having in its field the north pole point, and pointed out how, after proper corrections, an improved location of the pole could be obtained as the common center of the trail arcs. The results are excellent, and bid fair to give much better values for declination than those obtained by other methods.

The paper was discussed by Professor Rees, Mr. Post and Professor Hallock.

The second paper was by **P. H. Dudley,** entitled THE COMPLETION OF RELAYING THE TRACK OF THE BOSTON AND ALBANY RAILROAD WITH 95-LB. RAILS. Mr. Dudley outlined the introduction of rails of improved material and section, and the gradual relaying of this line, showing how greatly the road was improved at all points, how heavier loads were carried, and how a gain was obtained in all directions. Meeting then adjourned.

W. HALLOCK,
Secretary of Section, pro tem.

SECTION OF BIOLOGY.

JANUARY 10, 1898.

Professor Osborn in the chair, fifty-six persons present. The following programme was offered:

H. F. Osborn, THE ORIGIN OF THE MAMMALIA.

F. M. Chapman, THE DISTRIBUTION OF BIRDS IN THE STATE OF VERA CRUZ.

F. E. Lloyd, ON HYPERTROPHIED LEAF-SCALES IN PINUS PONDEROSA.

Professor **Osborn** showed that the speculation of recent authors (Cope, Baur, Osborn) regarding the ancestry of the mammalia turns back to certain Permian reptiles of the orders Theriodontia Owen, and Gomphodontia Seeley. He reviewed the characters of the skeleton of these Theriodontia, showing their unmistakable promammalian features. A number of persistent reptilian characters were also cited. In conclusion, the speaker said that these Theriodontia have the geological age required for ancestors of the mammalia, and are the only type of reptiles which exhibit mammalian affinities. Their great size and certain adaptive specializations alone bar any known type from direct ancestry of the much smaller earliest mammals; but this fact does not preclude the existence of very small unspecialized forms which may have developed into the mammalian type. Professor Osborn's paper was illustrated by lantern slides.

Dr. **Chapman** described the various types of vegetation and the altitudinal distribution of birds along the course of the two railroads running from the coast at Vera Cruz into the tablelands of the interior. His paper was also illustrated by lantern slides. In answer to Professor Britton's question whether the variations in air pressure have any influence in modifying bird structure, the speaker said apparently not. They undergo different pressure, as shown by height of flight, and seem to thrive equally well under differing conditions of barometric pressure.

Professor **Lloyd** showed that scales which subtend the fascicles of *Pinus ponderosa* are morphologically equivalent to leaves; and, when hypertrophied, these leaves closely resemble the leaf of the genus *Pseudotsuga.* The speaker suggested that the Pines may have been derived phylogenetically from a generalized form represented by *Pseudotsuga*, and that the hypertrophied leaves are atavistic.

GARY N. CALKINS,
Secretary of Section.

SECTION OF GEOLOGY.

JANUARY 17, 1898.

Professor Kemp in the chair, fifteen persons present.

The first paper was by Mr. **Arthur Hollick,** entitled FURTHER NOTES ON BLOCK ISLAND GEOLOGY AND BOTANY. The speaker gave a summary of his work done on Block Island in July, 1897, and particularly of his success in tracing eastward from Long Island the Amboy clays which had previously been determined by paleontological evidence on Staten Island, Long Island and Martha's Vineyard. Something like fifteen species of Middle Cretaceous flora, nine of them typical of the Amboy clays, have been found.

Mr. Hollick then classified the existing flora of the Island physiographically into that of the hills, peat bogs, sand dunes and beaches, salt marshes and salt water. In the course of his work he has added to the already published lists something like twenty-four new species, although it is not considered that this by any means completes the list of possible species that might be found in the springtime. The flora as a whole is distinctly that of a morainal country, and its nearest analogue is that of Montauk Point.

Mr. Hollick then offered some suggestions to account for the present peculiar flora of the island, and particularly for the absence of certain species that would be expected, and showed that two elements are to be taken into consideration, the geological and the human. Block Island is the only part of the terminal moraine along the New England coast which does not have accompanying the moraine a certain amount of plain land which would naturally allow a variety in the flora. It is presumable that Block Island also has been practically separated from the rest of the continent by a deep channel of more than twenty fathoms for a considerable time, and that even before the last depression of the land the island was connected with the mainland merely by a small peninsula. Hence the diversity of the flora as compared with the continent, because of the length of separation.

The speaker also mentioned the extensive archeological discoveries on the west shore of the island, and gave a list of the shells and implements discovered in several of the kitchen middens, and also of the bones of animals brought to light in the old fireplaces in the sand dunes. He made particular mention also of the great numbers of *Littorina*, the common periwinkle of Europe, which has never before been announced from Block Island. The paper was discussed by Professor Lloyd and Dr. Martin.

The second paper of the evening was by **Richard E. Dodge,** entitled SCIENTIFIC GEOGRAPHY IN EDUCATION. The speaker brought out the point that geography work may be classified into three divisions, that for the common schools, the secondary schools, and the universities, and outlined briefly a few suggestions as to how the subject matter might be treated scientifically in each of the groups, and the dependence of each group upon the others. He paid particular attention to the difficulties of securing scientific work in geography in the grade schools, and to the fact that geography at present is extremely unsatisfactory in most of our schools, probably because of the lack of inspiration owing to the neglect of the subject hitherto in the universities of the country. The paper was illustrated by the exhibition of cheap and easily procurable maps, that can be used for scientific geography work of several grades.

The meeting then closed with a few remarks by Professor **Kemp,** in reference to the famous classic, entitled LITHOGRAPHIÆ WIRCENBURGENSIS DUCENTIS LAPIDUM FIGURANTORUM, A POTIORI INSECTIFORMIUM PRODIGIOSIS IMAGINIBUS EXORNATÆ, SPECIMEN PRIMUM, written by J. B. A. Beringer in 1726. Professor Kemp summarized the work of the author in attempting to explain a great collection of pseudo fossils from a theological standpoint, the fossils having previously been made by some practical jokers and buried in the rocks for the author to find.

RICHARD E. DODGE,
Secretary of Section.

SECTION OF PSYCHOLOGY AND ANTHROPOLOGY.

JANUARY 24, 1898.

Professor Bliss in the chair. Fourteen names proposed for membership by the Secretary, were referred to the Council.

The following papers were then presented:

E. L. Thorndike, EXPERIMENTS IN COMPARATIVE PSYCHOLOGY.

H. J. Smith, RECENT ARCHEOLOGICAL INVESTIGATIONS IN BRITISH COLUMBIA.

L. Farrand, REPORT OF THE MEETING OF THE AMERICAN PSYCHOLOGICAL ASSOCIATION AT ITHACA.

CHARLES B. BLISS,
Secretary of Section.

REGULAR PUBLIC LECTURE.

JANUARY 31, 1898.

The Academy met in the Mott Memorial Library and listened to the second public lecture of the season, which was delivered by Professor **Henry H. Rusby,** of the College of Pharmacy, upon the subject, AN AFTERNOON ON A VENEZUELAN BAYOU.

Thirty persons were present and at the conclusion a vote thanking the speaker was passed.

J. F. KEMP,
Secretary.

REGULAR BUSINESS MEETING.

FEBRUARY 7, 1898.

The Academy met, with President Stevenson in the chair. About twenty-five members present. The minutes of the last meeting were read and approved. The Secretary presented the following nominations of new members from the Council:

CORRESPONDING MEMBER ELECTED.

Professor George E. Hale, Yerkes Observatory, Williams Bay, Wis.

RESIDENT MEMBERS ELECTED.

James Boyd, 12 Franklin street.
Alfred S. Brown, 160 West 76th street.
William Phelps Eno, 111 Broadway.
William W. Hoppin, 111 Broadway.
J. Morgan Howe, M.D., 58 West 47th street.
John S. Kennedy, 6 West 57th street.
Solomon Loeb, 37 East 38th street.
Edwin S. Marston, 20 William street.
George L. Nichols, 66 East 56th street.
Wheeler H. Peckham, 685 Madison avenue.
J. Hambden Robb, 23 Park avenue.
Henry H. Rogers, 26 East 57th street.
J. A. Roosevelt, 4 West 57th street.
H. L. Thornell, 51 West 73d street.
Spencer Trask, 27 Pine street.
John I. Waterbury, Morristown, New Jersey.
Frederick H. Wiggin, 55 West 36th street.
Alfred R. Wolff, 15 West 89th street.
C. A. Woodward, D.D.S., 49 West 36th street.
George Zabriskie, 45 West 48th street.

On motion the Secretary was instructed to cast a ballot for all the nominees, which was done. The Secretary presented the following recommendation from the Council, which, on motion, was adopted by ballot:

Resolved, That in consideration of the extremely valuable and conscientious services to the Academy of Professor D. S. Martin, his past dues be hereby remitted, and that he be made a Life Member.

AMENDMENTS TO BY-LAWS.

The Secretary laid before the Academy the following amendments to the by-laws, which had been recommended by the Council:

Chapter I, to add Article 4: "The number of Fellows shall be limited to 100."

Chapter V, Article 1, to add: "Past Presidents of the Academy, residents of New York City, shall be advisory members of the Council, with a right to be present at the meetings and to serve on committees, but without vote. They shall be notified of all meetings."

The Section of Astronomy and Physics then organized.

JAMES F. KEMP,
Secretary.

SECTION OF ASTRONOMY AND PHYSICS.

FEBRUARY 7, 1898.

The meeting was called to order with Mr. P. H. Dudley in the chair, twenty-one members and guests being present. The reading of the minutes of the last meeting was omitted, and the section proceeded with the programme of the evening.

H. Jacoby took the chair; and **P. H. Dudley** read a paper, illustrated by lantern views, entitled THE USE OF THE DUDLEY STREMMATOGRAPH FOR DETERMINING THE STRAINS PRODUCED IN RAILS BY MOVING TRAINS." He described the use of the instrument in recording tensional and compressive stresses in steel rails under various kinds of traffic, and stated that much greater stresses exist in steel rails than are commonly supposed to be caused by locomotives and cars standing on or moving over them. After a few supplementary remarks in reply to questions, Mr. Dudley resumed the chair, and **W. S. Day** read a paper entitled RECENT EXPERIMENTS CONCERNING THE SPECIFIC HEAT OF WATER. He discussed the results obtained by Rowland, Schuster, Bartoli, Griffiths and Miculescu, in measuring the mechanical equivalent of heat, and compared the results obtained by these scientists by means of curves. The paper was discussed by W. Hallock, H. Jacoby and others. After a few concluding remarks by Professor Jacoby, the meeting adjourned.

R. GORDON,
Secretary of Section.

SECTION OF BIOLOGY.

FEBRUARY 14, 1898.

Professor Osborn in the chair. Twenty-one persons present. The following programme was presented:

George S. Huntington, THE EPARTERIAL BRONCHIAL SYSTEM of THE MAMMALIA.

F. S. Lee, THE FUNCTION OF THE EAR AND LATERAL LINE IN FISHES.

Professor **Huntington's** paper dealt with the structure of the Bronchial System and with the pulmonary supply in various representatives of orders and families of the Mammalia. The conclusions reached are at variance, in their main points at least, with the views expressed by Professor Achy and with the generally accepted views in the text-books of human and comparative anatomy. The most primitive form appears to be Achy's "bilateral hyparterial type," represented by Achy in *Hystrix cristata*, by Weber in *Balæna mysticetus*, and now by the author in *Taxidea Americana*.

In the other mammalia a distinct and progressive series can be established between the primitive types of bronchial distribution and the most complex arrangement.

Among the many conclusions reached by Professor Huntington, we may note the following: The active agent in changing the architecture of the lung is not the pulmonary artery (Achy), but the migration of the cephalic primary trunk or its proximal secondary derivative for increasing respiratory area. The pulmonary artery, in the majority of forms, is lateral; hence, distinction in "dorsal" and "ventral" should be abandoned, etc.

Dr. Huntington's paper was well illustrated by lantern slides.

Dr. **Lee,** after describing his experiments on the auditory functions of certain fish, came to the following conclusions: (1) the otolithic organs mediate the perception of progressive movement; (2) all experiments for demonstrating the power of hearing in the customary sense, have failed, but destruction of the organs of the lateral line, combined with removal of the large pectoral and ventral fins in some species (*Batrachus tau*) causes lack of appreciation of equilibrium, also central stimulation of lateral nerve causes coördinated compensating movements of the fins exactly similar to those caused by stimulation of the acoustic nerve. The inference then is that the organs of the lateral line are sense organs of equilibrium analogous to the ear; (3) the ear is a derivative of the lateral line.

Dr. Lee's paper was illustrated by models, charts and diagrams.

Dr. J. A. Blake was nominated for membership, and referred to Council.

GARY N. CALKINS,
Secretary of Section.

STATED MEETING.

FEBRUARY 21, 1898.

The Academy met with President Stevenson in the chair. Seventeen members present.

The Secretary presented the following nominations for resident membership:

Robert F. Cornish, 123 Claremont avenue, Montclair, N. J.

Mrs. Henry Draper, 271 Madison avenue, New York.

Rev. Dr. Henry Mitchell McCracken, D.D., LL.D., New York University.

Mr. G. F. Kunz presented a circular relating to the proposed dinner of the Scientific Alliance and urged all the members of the Academy to be present.

SECTION OF GEOLOGY AND MINERALOGY.

FEBRUARY 21, 1898.

Professor Kemp in the chair. In the absence of the Secretary, Mr. Gilbert van Ingen was elected Secretary, *pro tem.*

The first paper was by **George F. Kunz,** entitled A RECENT DISCOVERY OF HUGE QUARTZ CRYSTALS IN THE WEST. The crystals were found in the neighborhood of Grass Valley, Cal., in placer gold mines and, although somewhat waterworn, are reported to be of great size and clearness. One is said to weigh a ton. The paper was discussed by Messrs. Levison and Kemp.

The second paper related to the exhibition of recent accessions of rare minerals, loaned for the purpose, by Professor **A. J. Moses.** Among the rest a large specimen of cellular rock with coats of Huantahajite, the whole being 8 inches square, was of particular interest. In the absence of Professor Moses the specimens were commented on by the Chairman and by Professor Chester.

The third paper was by Professor **F. D. Chester,** entitled KRENNERITE FROM CRIPPLE CREEK, COL. The speaker remarked on the rarity of the mineral and described his good fortune in obtaining a specimen with crystals capable of being measured, which were now being studied by Professor Penfield of Yale. The paper led to a considerable discussion upon the occurrence of the telluride ores, by Messrs. Caswell, Chester, Kunz and Kemp.

Professor **Kemp** then exhibited some specimens of the Nepheline Syenite from Dungannon, Ont., which he had received from Mr. F. J. Pope, and which showed crystals of Corundum of large size, forming an original mineral in the rock.

Dr. **W. G. Levison** exhibited some microscopic mounts of minerals in small pasteboard boxes.

A paper by **Stuart Weller,** entitled DESCRIPTION OF DEVONIAN CRINOIDS AND BLASTOIDS FROM MILWAUKEE, WIS., was read by title.

On motion the meeting adjourned.

GILBERT VAN INGEN,
Secretary, pro tem.

ANNUAL BUSINESS MEETING.

February, 21, 1898.

The Academy met with President Stevenson in the chair. Fifty persons present. There being no minutes to read, the President called for the Annual Reports of the various officers.

Report of the Recording Secretary.

The year now closing has been a successful and gratifying one in the history of the Academy. The meetings have been well attended, the quality of the papers good, and the general interest in the affairs of the organization has been pronounced. The membership has increased beyond any previous figure in its history.

There have been nine meetings of the Council, nine regular business meetings of the Academy, twenty-two additional stated meetings, five public lectures, one public reception, and two receptions to distinguished scientific visitors from abroad.

The Section of Astronomy and Physics has held eight meetings, with an average attendance of twenty; the Section of Biology has held eight, with an average attendance of twenty-four; the Section of Geology and Mineralogy eight, with an average of thirty-three; the Sub-section of Philology three, averaging twenty-seven; and the Sub-section of Psychology and Anthropology four, with about the same number.

A total of eighty-three papers has been presented, not including Public Lectures, which may be classified as follows:

Anatomy	1	Geology	16
Anthropology	5	Mechanics	1
Archeology	2	Mineralogy	4
Astronomy	6	Paleontology	8
Botany	1	Philology	5
Civil Engineering	1	Physics	9
Chemistry	4	Psychology	2
Geography	3	Zoölogy	18

Fifty-one new members have been elected, nine have resigned, and three have died, leaving a total of 330 on the Secretary's list, a gain of 39 over last year. As stated above, the resident membership of the Academy is now the largest in its history. One Honorary Member has been elected and ten nominations are pending. One Corresponding Member has been elected and the nominations of fifteen are pending. Nineteen Resident Members have been elected Fellows.

In connection with the publications the Council has decided that it is inadvisable to issue two octavo series and a quarto. The *Transactions* will therefore be discontinued with Volume XVI and will be merged into the ANNALS, beginning Volume XI of the latter. While the same size of page will be preserved a new and more desirable font of type has been chosen. The records of the meetings will be printed separately from the scientific papers. The volumes will also run coincidently with the calendar years.

The by-laws have been amended so as to abolish the fee for election as Fellow. And so as to limit the number of Fellows to one hundred.

The public reception of the Academy in March last passed off most successfully and the exhibition has now become an annual event, anticipated both within and without the Academy.

The Academy extended to Sir Archibald Geikie in May last a reception which proved a very enjoyable occasion; and in October offered its hospitalities to Dr. Albrecht Penck.

Respectfully submitted,
J. F. KEMP,
Recording Secretary.

ANNUAL REPORT OF THE TREASURER.

RECEIPTS.

Balance on hand as per last Annual Report.......	$394.89
Contribution to Audubon Fund	100.00
Income of Audubon Fund....................	89.86

Income of Publication Fund		$60.00
" Permanent Fund		300.14
Life Membership Fee		100.00
Initiation Fees		250.00
Annual Dues, 1894	$10.00	
" " 1895	30.00	
" " 1896	80.00	
" " 1897	2,035.00	
" " 1898	290.00	2,445.00
Proceeds Sale of Electrical Fixtures		20.00
		$3,759.89

DISBURSEMENTS.

Net Cost of Publishing Annals	$690.14
Net Cost of Publishing Transactions	1,033.71
Expenses of Recording Secretary	380.68
" Secretary of Biological Section	15.22
" Librarian	82.46
Cost of Accession to Library	14.13
Expenses of Treasurer	31.63
Janitorial Services	48.00
Rent of Rooms, Oct. 1, 1897, to Jan. 1, 1898	70.00
Insurance Premium	19.37
Expenses of Lectures	58.00
" Fourth Annual Reception	546.52
" Moving	32.63
	$3,022.49
Balance, Cash now on hand	737.40

DETAILS OF PERMANENT FUND.

Balance on hand as per last Annual Report	$348.68
Life Membership Fee received during the year	100.00
Initiation Fees received during the year	250.00
Balance now on hand	$698.68

DETAILS OF AUDUBON FUND.

Contribution received from Mrs. Esther Hermann	$100.00
Income from Bond and Mortgage Investment	89.86
Charged back to Publication Fund	23.00
Balance now on hand	$212.86

DETAILS OF PUBLICATION FUND.

Income from Bond and Mortgage Investment		$60.00
Credited back to Audubon Fund	$23.00	
Credited to General Income a/c	37.00	
	$60.00	

DETAILS OF GENERAL INCOME ACCOUNT.

Balance brought down as per last Annual Report		$46.21
Income from Permanent Fund		300.14
" " Publication Fund		37.00
Proceeds Sale of Electrical Fixtures		20.00
Received for Annual Dues		2,445.00
		$2,848.35
Less:		
Net Cost of Publishing Annals and Transactions		$1,723.85
Expenses of Officers		509.99
Rent of Rooms, Janitorial Services and Cost of Moving		150.63
Cost of Accessions to Library	$14.13	
Cost of Lectures	58.00	
Cost of Fourth Annual Reception	546.52	
Insurance Premiums	19.37	$3,022.49
Deficiency in Income to meet Current Expenses		174.14

SUMMARY.

Balance to credit of Permanent Fund	$698.68
" " Audubon Fund	212.86
	$911.54
Less Deficit in General Income	174.14
Balance, Cash on hand	$737.40

Assets.

Cash in Bank		$737.40
Investments in Bonds and Mortgages,		
a/c Permanent Fund	$8,402.75	
a/c Publication Fund	1,800.00	
a/c Audubon Fund	1,797.25	$12,000.00
Annual Dues, in arrears,		
For 1895	20.00	
" 1896	140.00	
" 1897	310.00	470.00
Total		$13,207.40
As against amount last year		12,644.89

Respectfully submitted,
C. F. Cox,
Treasurer.

On motion the report was referred to the Finance Committee for auditing.

HONORARY MEMBERS ELECTED.

The following nominations of Honorary Members were then presented from the Council:

Professor Arthur Anweers, Berlin.

Professor W. K. Brooks, Johns Hopkins University, Baltimore.

Dr. David Gill, Astronomical Observatory, Cape of Good Hope.

Dr. George W. Hill, Nyack, N. Y.

Professor E. Ray Lankester, Oxford, England.

Professor Albrecht Penck, Vienna, Austria.

Professor W. Pfeffer, Leipzig, Germany.

Professor Hans Reusch, Christiania, Norway.

Professor Karl von Zittel, Munich, Germany.

Professor R. Virchow, Berlin.

On motion, the Secretary was instructed to cast a ballot for all the nominees, which was done and they were declared elected.

CORRESPONDING MEMBERS ELECTED.

The following nominations of Corresponding Members were presented from the Council:

Professor F. D. Adams, Montreal.
Professor W. B. Balfour, Edinboro, Scotland.
Professor George Baur, Chicago.
Dr. William Carruthers, British Museum, London.
Professor T. C. Chamberlin, Chicago.
Professor William M. Davis, Cambridge, Mass.
Dr. A. Franchet, Paris.
Professor J. P. Iddings, Chicago.
Professor C. S. Minot, Boston.
Dr. George Murray, British Museum, London.
Professor W. B. Scott, Princeton, N. J.
Professor C. O. Whitman, Chicago.
Professor H. S. Williams, New Haven.
Mr. C. D. Walcott, Washington.

On motion the Secretary was instructed to cast a ballot for all the nominees, and they were declared elected.

ELECTION OF OFFICERS.

The Academy then proceeded to the election of officers for the ensuing year. The following ticket was elected by ballot:

President, Henry F. Osborn.
1st Vice-President, Nathaniel L. Britton.
2d Vice-President, James F. Kemp.
Corresponding Secretary, William Stratford.
Recording Secretary, Richard E. Dodge.
Treasurer, Charles F. Cox.
Librarian, Arthur Hollick.

Councilors, Charles L. Bristol, Bashford Dean, Charles A. Doremus,, William Hallock, Harold Jacoby, Lawrence A. McLouth.

Curators, Harrison G. Dyar, Alexis A. Julien, George F. Kunz, Louis H. Laudy, William D. Schoonmaker.

Finance Committee, Henry Dudley, John H. Hinton, Cornelius Van Brunt.

ANNUAL ADDRESS OF RETIRING PRESIDENT, J. J. STEVENSON.

On the announcement of the election, President Osborn took the chair and assumed control of the meeting. Retiring President **Stevenson** then delivered the annual Presidential Address upon the subject, THE DEBT OF THE WORLD TO PURE SCIENCE. The address appears in the ANNALS, Vol. XI, pp. 177–192. At the conclusion of the address, President Osborn expressed the thanks of the Academy to the speaker, and the meeting adjourned.

REGULAR BUSINESS MEETING.

MARCH 7, 1898.

President Osborn in the chair, fifteen members present. Minutes of last meeting read and approved.

The amendments to the by-laws proposed at the February meeting were both carried.

The Secretary presented for the Council the following names for Resident Membership, and he was authorized to cast one ballot for the list, which was done.

RESIDENT MEMBERS ELECTED.

Robert H. Cornish, 123 Claremont avenue, Montclair, N. J.

Henry Mitchell MacCracken, D.D., LL.D., New York University.

Dr. Joseph A. Blake, 437 West 59th street.

Mrs. M. A. P. Draper, 271 Madison avenue.

MEMBERS PROPOSED.

The following nominations were read and referred to the council:

Life member, Miss Catherine W. Bruce, 810 Fifth avenue; nominated by J. K. Rees.

Resident members, S. B. Hoffman, Morristown, N. J. nominated by Harold Jacoby.

Douglass Burnett, 42 Livingston street, Brooklyn, N. Y.; nominated by P. H. Dudley.

The following paper was read by title, and referred to Publication Committee: THE NORTHROP COLLECTION OF CRUSTACEA, by Professor **Walter M. Rankin,** of Princeton, illustrated by three plates.

The Section of Astronomy and Physics then organized.

RICHARD E. DODGE,
Secretary.

SECTION OF ASTRONOMY AND PHYSICS.

MARCH 7, 1898.

Meeting was called to order by the Chairman, Mr. P. H. Dudley, there being eighteen persons present. The first business of the meeting was the election of officers for the ensuing year. Nominations being declared open, J. K. Rees nominated P. H. Dudley as Chairman. There being no other nominations, the Secretary was empowered to cast one ballot for Mr. Dudley; and he was declared elected Chairman. R. Gordon was nominated Secretary by W. Hallock. There being no other nominations, the Secretary was empowered to cast one ballot for him; and he was thereby declared elected.

The next business was the reading of papers.

Romeyn Hitchcock read a paper entitled, INDUSTRIAL APPLICATIONS OF OXYGEN in which he described a gas enriched by oxygen for the purpose of increasing its heating power. He compared the composition of this gas, with which experiments have been carried on recently, with that of several of the usual gases commercially employed for lighting and heating. After brief discussion, **W. Hallock** described a MAKE-CIRCUIT PENDULUM, and showed a working model of the same. After some discussion, the meeting adjourned at 9:20 P. M.

R. GORDON,
Secretary of Section.

STATED MEETING.

MARCH 14, 1898.

President Osborn in the chair.

Secretary read the following nominations of committees made by the President, from the body of the Council for the ensuing year.

Committee on Publication: President and Secretary, Professors Dean, Jacoby, McLouth, Kemp and Britton.

As *representatives of the New York Academy of Sciences in the Scientific Alliance:* The President, Professor Stevenson and Mr. Cox.

Secretary then made announcement of the proposed grant of the Newberry Fund for the ensuing year.

Section of Biology then formed.

RICHARD E. DODGE,
Secretary.

SECTION OF BIOLOGY.

MARCH 14, 1898.

Professor Wilson in the Chair. Twenty-three persons present. The following program was offered:

1. **B. B. Griffin,** A DESCRIPTION OF SOME MARINE NEMERTEANS FROM PUGET SOUND AND ALASKA.
2. **W. H. Hornaday,** THE DESTRUCTION OF BIRDS IN THE UNITED STATES.
3. **N. R. Harrington,** REPORT ON THE CRUSTACEA OF PUGET SOUND.
4. **H. E. Crampton, Jr.,** AN IMPORTANT INSTANCE OF INSECT COALESCENCE.

In the absence of the author, Mr. **Griffin's** paper was read by title.

Mr. **Hornaday** first described the method employed to reduce bird loss to figures. Circulars containing the following questions were sent out to trappers, guides, sportsmen and naturalists in all parts of the United States. (1) Are birds decreasing in your locality? (2) How many birds are there now compared with fifteen years ago? (3) What are the most destructive agents? (4) Are any birds becoming extinct? The answers came from all but four States and territories, and showed surprising agreement. The most destructive agencies are sportsmen, plume-hunters, boys after eggs, pot-hunters, fire, English sparrows, etc.; and through these it has been estimated that there has been a decrease of about 46% during the last fifteen years. It was shown that game and edible birds are becoming scarce, and that song birds are being used for food in their stead; that plume-birds are becoming extinct, and that destructive agencies are increasing. Mr. Hornaday concluded with an appeal for more drastic measures in our game laws and for their careful execution. The paper was discussed by the Chairman, by Professor Osborn and by Mr. Mathews.

Mr. **Harrington's** report was based on the Crustacea collected at Puget Sound in 1896, and worked up by W. T. Calman, University College, Dundee, Scotland. It dealt with sixty-three species, some three of which were new. One of the new species, a parasite, *Pseudione giardi*, is interesting because males, female, and larva, were all found on a single specimen of its host *Eupagurus ochotensis;* another new species, *Polycheria osborni* is interesting because the only other known representative of the genus is found in the Antarctic region. The entire collection was made up as follows: *Macrura*, 15 species (13 of which were shrimps); *Brachyura*, 34 species; *Isopoda*, 6 species; *Amphipoda*, 3 species; Copepoda, 1 species.

Mr. **Crampton** spoke of his experiments on insect-grafting, and of one case in particular where the colors of the scales of one species were imposed upon the scales of another. The paper was discussed by Dr. Dyar and others.

The Secretary of the Academy notified the Section that the income of the John Strong Newberry Fund of the Council of the Scientific Alliance is to be awarded this year to a paleontologist or a zoölogist; and that a candidate should be chosen before the Council meeting of April 2d.

GARY N. CALKINS,
Secretary of Section.

STATED MEETING.

MARCH 21, 1898.

President Osborn in the chair. Minutes of meeting of February were read and approved. Secretary read the following paper by title:

THE PHYSIOLOGY OF SECRETION, by **Albert P. Mathews.**

Section of Geology and Mineralogy then formed.

RICHARD E. DODGE,
Secretary,

SECTION OF GEOLOGY AND MINERALOGY.

MARCH 21, 1898.

Professor Kemp in the chair. Thirty-four members present. Minutes of the last meeting were read and approved. Secretary read a letter from the Secretary of the Scientific Alliance in reference to the Newberry grant for paleontology or zoölogy.

The paper of the evening, illustrated by lantern, was by Dr. **Heinrich Ries,** entitled THE CLAY AND KAOLIN DEPOSITS OF EUROPE. Dr. Ries sketched briefly the geographical distribution of the Kaolin deposits, and their relation and comparison to similar deposits of America. He then gave special attention to the deposits of Great Britain, Belgium, Denmark, Germany and Austria, and mentioned briefly those found in other regions He described particularly the deposits of Cornwall, which are found in association with veins of Tin and Granite in regions where it is supposed that the Feldspar has been changed to Kaolin through the influence of fluoric fumes rising from below. These products are very pure, containing 97 ½ % of clay substance. He also spoke of the ball plastic clays found in southwestern England, which occur in lenses in large beds of sand, and are used to mix with non-plastic kaolins. Refractory clays are found in England and Scotland in the Carboniferous rocks, and are worked by underground mining. Impure clays, used for bricks, are particularly found in the vicinity of London. The Staffordshire blue brick, Fuller's earth and Bath brick deposits were sketched briefly, and the technological treatment in Great Britain, Germany and the United States was compared. The latter part of the paper was devoted to a rapid summary of the position, quality, uses and manner of mining of the famous clays of Bornholm, Denmark; of the Glasspot clays of southeastern Belgium; of the Kaolin deposits of Limoges, France, and the deposits of Prussia.

The paper was discussed by Dr. Julien, the Chairman, and Professor Hallock.

Professor **Henry F. Osborn** described the progress this year made through international effort in correlating the larger divisions of the fresh water Tertiary deposits of Europe by a study of the vertebrate remains.

Professor J. F. Kemp was nominated for *Chairman of the Section* for the ensuing year. There being no other nomination he was unanimously elected.

Dr. Heinrich Ries was nominated for *Secretary of the Section* and unanimously elected.

Academy adjourned at 9:15.

RICHARD E. DODGE,
Secretary of Section.

SUB-SECTION OF PHILOLOGY.

MARCH 28, 1898.

Meeting called to order by Chairman, Professor T. R. Price.

Officers for the ensuing year were elected: Lawrence A. McLouth, *Chairman;* A. V. Williams Jackson, *Secretary.*

Moved and carried to request Council of Academy to provide for four meetings of Philological Section for 1898–99.

The following papers were read and discussed:

E. G. Sihler, THE LATTER PART OF LUCRETIUS, AND EPICURUS *περὶ μετεώρων.*

J. R. Wheeler, THE NEWLY DISCOVERED POEMS OF BACCHYLIDES.

B. D. Woodward, THE VOWELS OF THE RUMANIAN AND OTHER ROMANCE LANGUAGES.

On account of the lateness of the hour, the reading of the last paper on the programme was postponed.

LAWRENCE A. MCLOUTH,
Secretary of Section.

REGULAR BUSINESS MEETING.

APRIL 4, 1898.

Academy met at 8:10, President H. F. Osborn in the chair.

Minutes of the last meeting were read and approved.

Secretary submitted the following list of names that had been approved by the Council for election, and was authorized to cast one ballot for the same, which was done.

MEMBERS ELECTED.

Miss Catherine W. Bruce, 810 Fifth avenue, Life Member
Douglas Burnett, 42 Livingston street, Brooklyn.
S. V. Hoffman, Morristown, N. J.

MEMBERS PROPOSED.

The following candidates for membership were read and referred to the Council under the rules:

Francisco G. P. Leão, Chancellor of the Brazilian Consulate.
C. E. Tripler, 121 West 89th street.
Dr. L. T. Chamberlain, 128 Fifth avenue.

The President appointed Mr. P. H. Dudley as the *representative of the Academy in the Scientific Alliance*, in the place of Professor J. J. Stevenson, resigned.

The Secretary made announcement of the changes to be incorporated in the eleventh volume of the ANNALS, now under way, with certain new regulations in reference to the printing of papers, and gave a statement of recent business transacted by the Council.

Section of Astronomy and Physics then organized.

RICHARD E. DODGE,
Secretary.

SECTION OF ASTRONOMY AND PHYSICS.

April 4, 1898.

The Section organized with Mr. P. H. Dudley, the Chairman, presiding. There were sixteen persons present. After the reading of the minutes of the last meeting, the following papers were presented:

Mr. **W. G. Levison** showed a Photographed Eye-Piece Micrometer, and described the construction of it, also speaking of micro-organisms as a complication in washing photographic plates. He, in addition to this, described and showed a model of a simple phosphoroscope. The discussion on these subjects was participated in by W. Hallock, C. F. Cox, H. F. Osborn, and C. C. Trowbridge.

The next paper was entitled A Modification of Mance's Method of Measuring Battery Resistance, by **W. S. Day.** This was treated mathematically by Dr. Day at considerable length. After this **Frank Schlesinger** read a short paper upon The Præsepe Group, mentioning the measurement and reduction of the Rutherford photographs of this group. After a few questions by members on the subject of the measurements the meeting adjourned.

Reginald Gordon,
Secretary of Section.

SECTION OF BIOLOGY.

April 11, 1898.

Professor Wilson in the chair. Eighteen persons present. Election of sectional officers for ensuing year. Dr. Dean seconded by Professor Stratford, moved that Professor Wilson and Mr. Calkins be reëlected to their respective offices, and the Secretary was directed to cast one affirmative ballot.

The following programme was announced:

1. **O. S. Strong,** A New Point on the Innervation of the Lateral Line Organs.

2. **A. P. Mathews,** THE PHYSIOLOGY OF SECRETION.
3. **G. N. Calkins,** THE ORIGIN OF PROTOZOAN NUCLEI.
4. **F. C. Paulmier,** SPERMATOGENESIS IN HEMIPTERA.

Dr. Strong explained some exceptions which have been urged to the view that the lateral line organs are innervated exclusively by special roots having a common center in the medulla. Among these exceptions is the innervation of a certain canal-organ by a branch of the glossopharyngeus instead of by a lateral line nerve proper. Dr. Strong showed that, close to the medulla in the young dog-fish (*Squalus acanthias*) a small intracranial bundle of fibers becomes detached from the lateral line root, and fuses with the glossopharyngeus. This bundle retains its identity, shown by greater calibre, etc. On emerging from the auditory capsule the bundle becomes detached and passes to a canal organ. Similar fibers described by Kingsbury in *Amia*, would probably be found to have the same history.

The three other papers were read by title, the authors not being present.

H. E. CRAMPTON,
Secretary of Section, pro tem.

FIFTH ANNUAL EXHIBITION.

APRIL 13 AND 14, 1898.

The Fifth Annual Reception was held in the American Museum of Natural History, April 13 and 14, 1898, under the control of the following committee, assisted by the chairmen of fifteen departments of science: Henry F. Osborn, Reginald Gordon, Charles F. Cox, Gary N. Calkins, and Richard E. Dodge, Chairman.

The exhibition lasted two evenings and one afternoon, and was attended by an estimated number of more than 6,000 people. The annual lecture was given April 14th by Professor **George E. Hale,** of Yerkes Observatory, on "THE FUNCTION OF LARGE TELESCOPES." Several demonstrations of Liquid Air were given by Mr. Charles E. Tripler.

The programme and catalogue of this exhibition is printed as an appendix to Part I of Vol. XI of the ANNALS.

RICHARD E. DODGE,
Secretary.

STATED MEETING.

APRIL 18, 1898.

Academy met with Vice-President Kemp in the chair, in Schermerhorn Hall, Columbia University.

Minutes of the meeting for March were read and approved.

Letters of thanks from Professor J. P. Iddings and Frank P. Adams, accepting the honor of being elected Corresponding Members were read.

Having no further business, the Section of Geology and Mineralogy then formed.

RICHARD E. DODGE,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

APRIL 18, 1898.

Professor Kemp in the chair. Thirty-five members present.

Professor Kemp made a few opening remarks and was followed by Dr. **A. A. Julien** who read a paper entitled THE ELEMENTS OF STRENGTH AND WEAKNESS IN BUILDING STONES.

Dr. Julien called attention to the fact that in the testing of building stones little consideration is given to the causes influencing their various properties. In judging the resistance which a stone shows towards weathering, care should be taken to recognize the character of the forces to which it has been subjected. The strength of a stone bears no relation to its mineral components, but is dependent on the shape and arrangement of the mineral grains and the character of the cementing material. In considering the strength of a stone four facts have to be kept in mind, viz.: interlockment of the particles; coherence, dependent on the character of the cement and adhesion of the grains; rigidity and tension. The "quarry sap," Dr. Julien believes, plays a more important rôle than has hitherto been recognized, as it probably carries much of the cement in solution and deposits it only when the stone is exposed to the air. This accounts for the hardening of the stones after being quarried. A distinction should also be made between porosity due to cavities between the grains and interstices in the individual minerals. The former is a source of weakness, the latter not, although either may cause the rock to exhibit a high absorptive capacity. All of these points, which have an important bearing on the strength of building stones are best studied with the microscope. The paper was illustrated by means of sections thrown on the screen with a polarizing lantern. Discussion was by Professor Kemp and Mrs. Dudley.

The second paper of the evening was by **J. D. Irving** on CONTACT-METAMORPHISM OF THE PALISADES DIABASE.

Mr. Irving referred to the work done by Professor Osann and Andrae some years ago and stated that his results agreed with theirs, but recent railroad excavations at Shadyside had enabled him to obtain additional facts. The Diabase flow becomes denser, finer grained and porphyritic towards the contact, with a decrease of Hypersthene. In addition to zones found by Osann, Mr. Irving found: 1. A normal hornfels zone rich in Spinel. 2. A hornfels zone with brown basaltic hornblende layers. 3. Hornfels with an undeterminable isotropic mineral resembling Leucite. 4. Hornfels with Andalusite, gradually changing to Arkose farther from the contact. The Diabase is to be considered as an intruded mass and not a surface flow. The paper was discussed by Professors Kemp, Dodge, Dr. Hovey and Mr. White.

Owing to the lateness of the hour the reading of the other two papers on the programme was deferred until the next meeting.

Academy adjourned at 10:15.

HEINRICH RIES,
Secretary of Section.

SUBSECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

April 25, 1898.

President Osborn in the chair.

After some discussion, the section asked the chair to appoint a committee of four to confer with the council in reference to the number of meetings to be held by the Section of Psychology and Anthropology during the coming year. The committee appointed consisted of Messrs. Bliss, Farrand, McLouth and Boas.

The following papers were then presented:

J. D. Prince, Some Passamaquoddy Documents.

L. McWhood, A Method of Studying the Motor Effects of Music.

After the papers Charles B. Bliss was elected Secretary of the subsection for the coming year.

Charles B. Bliss,
Secretary of Section.

REGULAR PUBLIC LECTURE.

The third public lecture of the year was delivered Friday evening, April 29, 1898, at the Mott Memorial Library, by **James Douglass, Esq.,** of New York, on the subject: Fifty Years' Progress in Mining and Metallurgy in the United States.

The lecture was copiously illustrated by lantern slides, and was both descriptive and statistical. The changes in centers of production and the improvements in furnaces were shown for iron, copper and the precious metals. At the conclusion of the lecture there was passed a vote of thanks to Mr. Douglass.

Forty members and friends were present.

Richard E. Dodge,
Secretary.

STATED MEETING OF THE ACADEMY.

MAY 2, 1898.

Academy met at 8 P. M., Mott Memorial Library. President Osborn in the chair. In the absence of the Secretary, Mr. William Hallock was appointed Secretary, *pro tem.* Minutes of the last meeting were read and approved.

MEMBERS ELECTED.

The following candidates for election, approved by the Council, were read by the Secretary who was authorized to cast one ballot for them, which he did.

Dr. L. T. Chamberlin, 128 Fifth avenue.
Francisco G. P. Leão, 23 State street.
Charles E. Tripler, 121 West 89th street.

AMENDMENTS TO BY-LAWS.

The following amendments to the by-laws recommended by Mr. C. F. Cox, Mr. Wm. Hallock and Mr. Edmund B. Wilson, a committee acting for the Council, were read and laid on the table for one month, in accordance with the rules:

1. That Section 2 of Chapter I of the by-laws be repealed.
2. That a new section be added to Chapter I, entitled Section 2, as follows:

"Any Resident Member or Fellow, who shall resign because of removal to a distance from the city of New York, may be restored to Membership or Fellowship at any time upon his own application, by a vote of the Council, and without payment of initiation fee."

A series of letters of acceptance were read by the Secretary from several of the new Corresponding Members.

Section of Astronomy and Physics then organized.

WILLIAM HALLOCK,
Secretary, pro tem.

SECTION OF BIOLOGY.

MEETING OF MAY 9, 1898.

Professor Wilson in the chair, twenty-three persons present. The following programme was offered :

1. **C. L. Bristol,** MEASUREMENTS OF A LARGE LOBSTER CAUGHT OFF SANDY HOOK.

2. **H. L. Clarke,** NOTES ON BERMUDA ECHINODERMS, presented by C. L. Bristol.

3. **F. P. Keppel and G. N. Calkins,** REPORT ON THE HYDROIDS COLLECTED IN PUGET SOUND.

4. **E. B. Wilson,** ON THE STRUCTURE OF PROTOPLASM IN THE EGGS OF ECHINODERMS AND SOME OTHER ANIMALS.

5. In addition to the above Professor **Osborne** reported on some facts concerning a huge herbivorous Dinosaur, bringing out in particular the discovery of some hitherto unknown characters of the caudal vertebræ, and the peculiarly avian structure of the posterior cervical and the anterior dorsal vertebræ.

GARY N. CALKINS,
Secretary of Section.

SECTION OF GEOLOGY AND MINERALOGY.

MAY 16, 1898.

Professor Kemp in the chair. Ten persons present.

Minutes of the last meeting were read and approved.

Mr. **Geo. F. Kunz** exhibited specimens of Quartz crystals in massive Gypsum from Gallineo Springs, N. Mex., and announced the discovery of a new meteorite from Ottawa, Kansas.

The first paper on the programme was by Professor **D. S. Martin** on THE GEOLOGY OF COLUMBIA, S. C., AND ITS VICINITY. Professor Martin described the granitic and gneissic rocks of that region, and their residual products. He also commented on the character of the Potomac, Lafayette and Columbian formations which are well exposed in the railroad cuts south of the city.

The paper was discussed by Mr. Dodge and Dr. Ries.

The next paper of the evening was by Professor **Kemp**, entitled SOME REMARKS ON TITANIFEROUS MAGNETITES. The speaker discussed the formula of Ilmenite, and stated that it was probably a mixture of FeO, TiO_2, and n FeO_3. The amount of Titanium present in the titaniferous magnetites is very variable, running sometimes as high as 40% ; in the Adirondack ores it running 10–20%.

Magnetic methods of separation for the elimination of the Titanium have not yet proved successful. Nearly all of the titaniferous magnetites show small amounts of MnO, Cr_2O_3, CoO, NiO, V_2O_3 and MgO. The latter suggests the presence of Spinel. SiO_2 and Al_2O_3 have also been found, but Phosphorus and Sulphur are rare. Professor Kemp suggested that the rarer constituents might have some influence on the metallurgical behavior of the ore. The native and foreign occurrences of these ores were also alluded to.

Discussion of the paper was by Professor Martin, Dr. Ries and Mr. Kunz.

Owing to Dr. Ries' removal to Cornell University, his resignation as Secretary of Section was accepted, and Mr. Geo. F. Kunz elected Secretary for the remainder of the year.

Meeting adjourned at 10 P. M.

HEINRICH RIES,
Secretary of Section.

SECTION OF PHILOLOGY.

MAY 23, 1898.

The Section of Philology held its closing meeting for the year 1897 and 1898 on Monday evening, May 23d. The attendance numbered fifteen persons. Professor J. F. Kemp opened the session and presented Professor L. A. McLouth, the Chairman of the Section, who thereupon assumed the duties of presiding officer for the coming year.

Professor **T. R. Price** brought forward a contribution in which he gave the results of his study of SHALL AND WILL IN LIVING ENGLISH USAGE. Dr. Price's investigations were confined to works that have appeared since 1850, in order to get the results of present usage. He chose as typical writings (1) a file of the London *Spectator* from August, 1897, to January, 1898; (2) The Poems of Stephen Philips; (3) The Essay of Henley on Robert Burns; (4) The Poems of Matthew Arnold; (5) The Idyls of Tennyson that have appeared since 1850. He presented only that part of his paper which dealt with the first person; the second and third persons are reserved to be printed. His results showed that *shall*, *should* are the normal usage in the first person; *I will* and *I would* in best usage are regularly confined to the idea of volition. The distinction seems to be quite sharply made in the best writers; and the number of occurrences is equally balanced. Several of those present took part in the discussion that followed.

The second paper of the evening was by Professor **L. A. McLouth,** and was entitled, NOTES ON E. JOSEPH'S KURENBURG THEORY. Dr. McLouth emphasized the strong points in Joseph's monograph, but criticised the tendency which the writer showed at times, it seemed, somewhat arbitrarily to reconstruct the text on the basis of a preconceived theory. Dr. McLouth favored rather a more conservative method.

Shortly after ten o'clock the meeting adjourned.

A. V. WILLIAMS JACKSON,
Secretary.

STATED MEETING.

JUNE 6, 1898.

Academy met at 64 Madison avenue, Vice-President Britton in the chair. Minutes of the last meeting were read and approved.

The changes in the by-laws which were to be brought up for adoption at this meeting were laid over until October, a legal quorum not being present.

After a notice by the Secretary about the meeting place for next year, the Section of Astronomy and Physics organized.

RICHARD E. DODGE,
Secretary.

SECTION OF ASTRONOMY AND PHYSICS.

JUNE 6, 1898.

Regular monthly meeting of the Section was held on Monday, June 6th, at 8 P. M., the chairman, Dr. P. H. Dudley, presiding. There were nine members and guests present.

The minutes of last meeting were read and approved.

Dr. **P. H. Dudley** read a paper on STRAP RAILS OF THE MOHAWK AND HUDSON RAILROAD, and showed a specimen of the rail, rolled in the year 1826.

After a few general questions and remarks, Dr. Dudley described the improvement that has been made in the condition of the track of the Boston and Albany Railroad, by the use of heavy rails, especially on steep grades.

Professor **D. S. Martin** then read a paper entitled, ARCHEOLOGICAL NOTES NEAR COLUMBIA, S. C., and showed specimens of curiously marked pieces of pottery found in that locality; also, a very interesting shell that had probably been used as a drinking cup.

After brief discussion, the meeting adjourned at 9:25 P. M.

R. GORDON,
Secretary.

REGULAR BUSINESS MEETING.

OCTOBER 3, 1898.

Academy met at 12 West 31st street, at 8 P. M., Vice-President Kemp in the chair. The minutes of the last meeting were read and approved.

Proposed changes in the by-laws in reference to Corresponding and absent Members were referred back to the committee on by-laws, on request of the Secretary.

Section of Astronomy and Physics then organized.

RICHARD E. DODGE,
Secretary.

SECTION OF ASTRONOMY AND PHYSICS.

OCTOBER 3, 1898.

Section met on Monday evening, October 3, 1898, at 8 P. M., Vice-President J. F. Kemp in the chair. There were eighteen members and guests present.

The minutes of the meeting of June 6, were read and approved.

The Secretary then read a paper by Mr. **P. H. Dudley** on STREMMATOGRAPH RECORDS, giving some recent results obtained with the instrument under locomotives, and entire trains. Brief remarks were elicited by the paper, after which another by the same author was read by the Secretary, entitled OXYDATION OF RAILS IN TUNNELS. After a few remarks on the subject, the Section adjourned.

REGINALD GORDON,
Secretary.

SECTION OF BIOLOGY.

OCTOBER 10, 1898.

In absence of the chairman, Professor Wilson, Professor Osborn presided. Twenty-four persons were present.

Professor Osborn referred to the loss sustained by the Academy, and the Biological Sciences in general, through the death of Professor Baur, of Chicago, and of Dr. Arnold Graf, of New York.

Following the usual custom the meeting was devoted to accounts given by various members of their summer's work.

Professor **H. F. Osborn** described the different museums which he visited in Europe, giving a very brief account of the good and bad points of each. At Stuttgart he saw a unique and undescribed fossil *Hyrax* which Professor Fraas very generously gave him the pleasure of describing. The description was presented at the Meeting of the British Association in Cambridge.

Professor Osborn was followed by Professor **N. L. Britton,** who gave a resumé of the work accomplished during the summer on the building and grounds at the Botanic Garden in Bronx Park.

Professor **B. Dean** reported on a few results on the embryology of the Hag Fish, which he thinks is similar to that of the sharks. He also described the appearance of a South American Lung Fish (*Protopterus*) which was sent to him in a ball of dried mud.

Dr. **O. S. Strong** and Mr. **H. E. Crampton** reported briefly on the nature of the work accomplished at the Marine Biological Laboratory at Wood's Holl, bringing out particularly the fact of the cordial relations between the investigators of the Fish Commission and those of the laboratory.

Mr. **N. R. Harrington** related some interesting experiences in connection with his expedition to the Nile valley in quest of *Polypterus bishir.* The expedition, which was made possible by the generosity of Mr. Chas. H. Senff, was undertaken by Mr. Harrington and Dr. Reid Hunt. As guests of the Egyptian government they enjoyed unusual advantages in securing their ends, but only after repeated trials and discomforts and many disappointments did they finally get the fish.

Other brief reports were made by Professor Lloyd (on the botanic gardens of Germany), Dr. Brockway and Mr. Calkins.

At the suggestion of Professor Osborn and Dr. Dean a series of nominations for corresponding membership was sent to the Council.

GARY N. CALKINS,
Secretary.

REGULAR MEETING.

OCTOBER 17, 1898.

Academy met at 8 P. M., Vice-President Kemp in the chair. Twenty-five persons present. In the absence of the Secretary, reading of the minutes was dispensed with.

MEMBERS PROPOSED.

The following nominations for new members were presented for the Secretary by the chair:

Jacob M. Rich, 50 West 36th street; Ernest Foley, 108 East 62d street.

The nomination of Dr. Henry S. Washington, of Locust, N. J., was made by Mr. George F. Kunz. These three names were referred to the Council under the rules.

The following paper was read by title: ANNOTATED CATALOGUE OF THE FAMILY OF MURICIDÆ NORTH OF THE ISTHMUS OF PANAMA, by **Frank C. Baker,** Chicago.

Section of Geology and Mineralogy then organized.

RICHARD E. DODGE,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

OCTOBER 17, 1898.

Section met at 8 P. M., Professor Kemp in the chair, and twenty-two members present.

The first paper, by Professor **J. F. Kemp,** on the MINERALS OF THE COPPER MINES AT DUCKTOWN, TENN., gave a brief history of the mines, and described some of the processes employed in treating the ores and the character of the rocks and the associated minerals. The paper was illustrated with an extended series of lantern views of the mines and the works, and with a suite of specimens. Professor Kemp referred particularly to the extremely interesting crystals of Almandite Garnet which he showed, in which the faces of the hexoctahedron are strikingly developed, giving 48-sided forms, sometimes with small faces of the rhombic dodecahedron in addition. Zoisite also occurs in fine terminated crystals, and Limonite of remarkable iridescence.

The second paper, by Dr. **Arthur Hollick,** was entitled NOTES ON THE GLACIAL PHENOMENA OF STATEN ISLAND, and embodied the general results of several years of study and exploration by himself and others. The author outlined the topography of the island and the distribution of drift material upon it, and described the transported contents of the drift with relation to their sources. Most of the drift material is made up of the Triassic sandstone and shale from the adjacent mainland, ground up by the ice-sheet; but the boulders are largely brought from afar. They comprise material from all the fossiliferous beds of central New York, from the Potsdam to the Hamilton, but there is a great preponderance of Lower Helderberg and Schoharie grit. The fossils are in many cases finely preserved, have been collected in large quantities, very carefully studied and determined. The question as to the route by which they have come, over the hilly and almost mountainous regions lying between their source and their resting place is one of much interest.

An extended discussion followed the reading of this paper. Mr. van Ingen claimed that the course had probably been down the Mohawk Valley to that of the Hudson and then down the latter, rather than over the highlands of southern New York. Professor Stevenson suggested that the transportation over this long distance may have been due to repeated glacial movements, each transporting over a moderate distance.

The next paper was by Mr. **Francis C. Nicholas,** on the SEDIMENTARY FORMATIONS OF NORTHERN SOUTH AMERICA, and dealt with a large area of little-explored country between the Caribbean coast and the Northern Andes. It was illustrated by a most extensive and carefully labeled series of rocks, ores and minerals from many localities and horizons, to which it was impossible to do justice within the limits of the evening. Among many interesting points described and illustrated with specimens was the agency of sun's heat as a rock-disintegrator;

the changes of day and night temperature in high regions in the tropics producing a fracturing of the superficial portions of exposed rocks, comparable in result to the action of frost in higher latitudes.

The last paper was by Mr. **Geo. F. Kunz,** upon A METEORIC STONE THAT FELL AT ANDOVER, MAINE, ON AUGUST 5, 1898, with exhibition of the stone, or rather about half of it. The fall took place early in the morning of a cloudy and threatening day, so that the sound made by the meteor, which was heard for many miles around, was generally supposed to be thunder. A dark cloudy trail, like a dense smoke, followed and marked the path of the body through the air. Its course was from the north, southward, and in coming down it tore its way through a group of large trees, struck a heavy stone in a wall near the ground and buried itself in the earth. Here it was found two days later, by that time entirely cooled. The specimen is a typical stony meteorite, with a thin black crust on the outside, and of a bright pale gray on the broken surface, with very little iron. It weighs about 7 pounds, and its description will appear, later.

GEO. F. KUNZ,
Secretary.

REGULAR MEETING.

OCTOBER 24, 1898.

Academy met with President Osborn in the chair. Reading of the minutes was dispensed with.

MEMBERS PROPOSED.

The following nominations for Resident Membership were read by the Secretary and referred to the Council under the rules:

MATURIN L. DELAFIELD, JR., 56 Liberty street.

R. ELLSWORTH CALL, 201 Lenox avenue, Flatbush, Brooklyn.

After a notice from the President in reference to the forthcoming meeting of the American Society of Naturalists, the Section of Psychology and Anthropology organized.

RICHARD E. DODGE,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

OCTOBER 24, 1898.

At the close of the regular meeting of the Academy, the Section of Anthropology and Psychology organized by appointing Professor Osborn Chairman *pro tem.*

Professor **J. McKeen Cattell** presented a paper entitled SOME ANTHROPOLOGICAL TESTS AND MEASUREMENTS, showing two new instruments. Reports of summer field work in anthropology were then made by Dr. **Livingston Farrand** and Mr. **Harlan I. Smith,** who spoke of their work on the northwest coast, and by Dr. **H. M. Saville** and Dr. **Carl Lumholtz,** who gave an account of explorations in Mexico.

CHARLES B. BLISS,
Secretary.

PUBLIC LECTURE.

OCTOBER 31, 1898.

The first public lecture of the season of 1898–99 was given by Professor **George W. Blodgett,** of the Boston and Albany Railroad, on RAILWAY SIGNALLING, PAST AND PRESENT. The lecture was under the auspices of the Section of Astronomy and Physics.

The lecturer was introduced by the Chairman, Mr. P. H. Dudley, who gave a brief summary of railway progress within the last few years.

Professor Blodgett spoke simply and very interestingly for an hour and a-half, sketching the various systems of railway signals in use on the more important railroads, and illustrating his remarks with an extensive series of well-chosen lantern slides. The lecture was free from technicalities, and very pleasing.

About sixty guests were present, and at the close of the lecture a vote of thanks was unanimously extended to Professor Blodgett.

RICHARD E. DODGE,
Secretary.

REGULAR MEETING.

NOVEMBER 7, 1898.

Academy met with Mr. P. H. Dudley presiding.

There not being a quorum present, the business meeting was postponed to Monday, November 14th.

RICHARD E. DODGE,
Secretary.

SECTION OF ASTRONOMY AND PHYSICS.

NOVEMBER 7, 1898.

Stated meeting, Monday, November 7, 1898, Dr. P. H. Dudley presiding. Eight members present.

Professor **J. K. Rees** read a paper on VARIATION OF LATITUDE AND THE CONSTANT OF ABERRATION. In this he explained the scope of the work that had been done in this direction at Columbia University during the years 1894–98, gave a summary of the results, and stated that in future these observations would be carried on chiefly at Government observatories. Accompanying the paper were plotted curves to show the displacement of the earth's axis from time to time, based upon these observations.

The Section then adjourned.

R. GORDON,
Secretary.

ADJOURNED BUSINESS MEETING.

NOVEMBER 14, 1898.

Academy met at 8 P. M., President Osborn in the chair. Reading of the minutes of the previous meeting was dispensed with.

MEMBERS ELECTED.

The following names for membership were reported from the Council, and the Secretary was instructed to cast one ballot for the list, and they were thereby elected.

M. L. Delafield, Jr., 56 Liberty street. Life Member.
Ernest Foley, 108 East 62d street.
Dr. H. S. Washington, Locust, N. J.
Jacob M. Rich, 50 West 38th street.
R. Ellsworth Call, 279 Winthrop street, Flatbush, Brooklyn.

MEMBERS PROPOSED.

The following nominations for membership were made and referred to the Council:

Rev. A. B. Kendig, 86 Vernon street, Brookline, Mass.
Daniel C. Beard, 204 Amity street, Flushing, L. I.
B. Talbot B. Hyde, 82 Washington street. Life Member.
J. D. Irving, Columbia University.
Professor Graham Lusk, New York University Hospital and Medical College.
Marshall A. Howe, Columbia University.
Dr. L. H. Reuter, Merck Building, New York City.
Mason A. Stone, 20 East 66th street.
M. H. Beers, 408–410 Broadway.
Dr. Ivan Sickels, 17 Lexington avenue.
Alfred Douglas, 170 West 59th street.
Dr. Max Meyer, 159 West 103d street.
William L. Mason, 170 Fifth avenue.
William Wicke, First avenue and 31st street.
Edward R. Hewitt, 119 East 18th street.
Professor Charles H. Judd, New York University.

A series of proposed by-laws, presented by the Council, were read by the Secretary, and laid on the table until the next business meeting, according to the rules.

RICHARD E. DODGE,
Secretary.

SECTION OF BIOLOGY.

MEETING OF NOVEMBER 14, 1898.

Sixteen persons present.

The resignation of Professor E. B. Wilson was read and accepted by the section. Professor Frederick S. Lee was unanimously elected chairman of the section.

The following programme was then presented:

1. **H. F. Osborn.** ON THE PRESENCE OF A FRONTAL HORN IN ACERATHERIUM INCISIVUM KAUP.

2. **H. F. Osborn.** ON SOME ADDITIONAL CHARACTERS OF DIPLODOCUS.

3. **W. D. Matthew.** ON SOME NEW CHARACTERS OF CLÆNODON AND OXYÆNA.

4. **W. E. Ritter.** ON THE ASCIDIANS COLLECTED BY THE COLUMBIA UNIVERSITY PUGET SOUND EXPEDITION OF 1896. Presented by Dr. Dean.

5. **J. P. McMurrick.** REPORT ON THE HEXACTINIÆ OF THE SAME EXPEDITION. Presented by Dr. Calkins.

Professor **Osborn** described the appearance of an hitherto unrecognized frontal horn on the skulls of *Aceratherium incisivum* Kaup; a discovery of great importance as it practically removes *Aceratherium* from the group to which it gives its name and ranges it with the rhinoceroses. Professor Osborn suggested that it may possibly be an ancestor of *Elasmotherium.*

In discussing the paper Dr. Wortman criticised the common tendency to create types based an a single character, citing in support of his suggestion the considerable variations to which single individuals of a species are subject, and giving one or two instances where errors have occurred.

In his second paper Professor **Osborn** described the structure of the vertebræ of *Diplodocus,* bringing out in considerable detail the variations in the sacrum of the herbivorous Dinosaurs.

Dr. **Matthew** briefly described the characters of the teeth, manus and pes of *Clænodon,* a form belonging to one of the three families, Arctocyonidæ, which gave rise to the present-day Carnivora. The structure of the wrist bones in particular brings this form almost within the limits of the Carnivora and Dr. Matthew regards it as a primitive bear which lived on fruits, honey or other soft foods.

Oxyæna another typical Creodont, was also described by Dr. Matthew, the principal points brought out being the disproportion of the brain case, limbs and lower jaws.

In the discussion which followed, Professor Osborn showed that while *Clænodon* undoubtedly possesses many precocious bear-like structures there are many difficulties to be pushed aside before it can be considered the direct ancestor of the bear. There are transitional forms for example between dogs and bears, as shown in certain types of teeth (*Amphicyon*), while on the other hand there is a marked difference in the size of the brain of the Arctocyonidae and that of the bears ; the brain of the former resembling more closely the brain of the marsupials. If the *Amphicyon* evidence is of a sufficient phylogenetic value the bear line must have arisen much later than Dr. Matthew believes.

Dr. Lee also questioned the advisability of ascribing particular functions to specialized structures, a criticism which Dr. Matthew met by saying that in this case the relation of structure to function was in the nature only of an hypothesis ; an explanation supplemented by Professor Osborn's statement that in all such cases it is necessary to have some working hypothesis, although each hypothesis is considered merely tentative.

At the request of Dr. Dean, Mr. **Richard Weil** was asked to give the main results of his observations on the DEVELOPMENT OF THE OSSICULA AUDITUS IN THE OPOSSUM. Mr. Weil finds that both the malleus and incus are derived from the mandibular arch and have no connection with the hypidean, thus confirming the older German view.

The other papers on the programme presented by Dr. Dean and Dr. Calkins were strictly technical and received only brief mention.

GARY N. CALKINS,
Secretary.

REGULAR MEETING.

NOVEMBER 21, 1898.

Academy met with Vice-President Kemp in the chair.

Reading of the minutes was dispensed with.

MEMBERS PROPOSED.

The following nominations were read and referred to the Council:

Fred W. Franklin, 700 West End avenue.
John I. D. Bristol, 1 Madison avenue.
Rudolph Keppler, 28 West 70th street.

Academy adjourned.

RICHARD E. DODGE,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

NOVEMBER 21, 1898.

Section met at 8 P. M., the Chairman, Professor Kemp presiding. Minutes of last meeting were read and approved.

The first paper of the evening was by Dr. **J. H. Pratt,** State Mineralogist of North Carolina, on the OCCURRENCE, ORIGIN AND CHEMICAL COMPOSITION OF CHROMITE. An abstract follows.

Chromite has only been found in the peridotites and allied basic magnesian rocks and in the alteration products of these rocks. The mineral occurs in grains or crystals and in imbedded masses near the boundary of lenticular masses of peridotite that have been shown to be of igneous origin. The chromite occurs in the fresh as well as in the altered peridotite.

The theory advanced by the author for the origin of the chromite is that the mineral was held in solution by the molten mass of peridotite and crystallized out from the molten magma as this began to cool.

The fused mass of rock would hold the different minerals in solution, and as this began to cool, the minerals would separate out, not according to their fusibility but according to their solubility in the fused magma. The more basic minerals being the more insoluble would be the first to separate out and in the present case would be the minerals chromite, spinel and corundum. This crystallizing or solidifying out from the molten magma would take place first on its outer boundaries, for here it would cool first. Convection currents would tend to bring new supplies of material to the outer zone where the chromic oxide would be deposited as chromite.

This theory would account for all the vagaries of chromite deposits, their pockety nature; the shooting off of apophyses from the main masses of the chromite into the peridotite, the widening and pinching of the chromite lodes; and the apparently non relation or connection of one pocket of chromite with another. The masses of chromite that are found in the midst of a peridotite formation, which at the present time are isolated and have no connection with each other, were at the time of their formation part of the chromite concentrated near the border of the peridotite.

In mining for either chromite or corundum it is in that deposit found near the contact of the peridotite with the gneiss that a large deposit of either of these minerals would be expected to be found.

Chemical Composition.—From an examination of the analysis of chromite it is shown that a nearly pure chromite, with the composition FeOAO, is rarely found in nature. With the exception of three, in all the chromite analyses examined, alumina and magnesia were invariably present, and this would seem to indicate that the molecule of the mineral now called chromite is not pure FeOAO, but is a combination of the three isomorphous molecules; $FeOA_2O_3$; $MgOA_2O_3$; and $MgOAl_2O_3$. The ratio of the $FeOA_2O_3$ to the $MgOA_2O_3$ or $MgOAl_2O_3$ is generally 8 to 10 : 1.

An analysis of a chromite from Webster, Jackson Co., N. C., gave as A_2O_3 — 95%; Al_2O_3 — 29.28%; FeO — 13.90, and MgO — 17.31. This gave for the formula of the chromite, ratio of the molecule $MgOA_2O_3$ observed in any of the chromite examined.

It was noticed that the magnesia usually varied with the alumina, those rich in alumina being correspondingly rich in magnesia.

The second paper was by Professor **D. S. Martin**, entitled NOTES FROM THE SEMI-CENTENNIAL MEETING of A. A. A. S.

Dr. Martin summarized the more important papers in geology given at the 1898 meeting of the Association, and particularly the papers devoted to glacial phenomena.

Section adjourned at 9:45.

G. F. KUNZ,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

NOVEMBER 28, 1898.

Section met at 8 P. M., with President Osborn and the Secretary in charge of the meeting.

The following paper was read by title: A PALEOZOIC TERRANE BENEATH THE CAMBRIAN, by **Geo. F. Matthew,** of St. John, N. B.

The first paper of the evening was by Dr. **Geo. V. N. Dearborn,** entitled, THE EMOTION OF JOY. Brief summary of a monograph in experimental and descriptive physiological psychology. "Somewhat in proportion to its pleasantness, an emotional extramotion of 'expression' consists in general expansiveness and outwardly in contraction of the extensor muscles; this is, in particular, true of the smile and laugh of joy, the muscles concerned in which, from the early fœtal cervical flexion are properly of the extensor sort." Four series of experiments (nearly 3,500 in number), on the hands, head, arm, and leg, prove the correlation between pleasantness and organic sensation. The regular occurrence of habitual inhibitions, due to the complex conditions of civilized social development, supplies the apparent deficiency of the kinæsthetic theory in case of the emotions of man. Human "emotions" are not so in the biologic sense, but rather concrete expressions of the affective social consciousness at present quite indefinite.

The second paper of the evening was by Mr. **E. G. Dexter,** entitled THE INFLUENCE OF THE WEATHER ON MENTAL ACTIVITIES OF CHILDREN, and was devoted to the particular study of the apparent influence of the weather on the children of Denver, Col., as shown by the study of some 600 cases of punishment inflicted upon children during a period of years. It was illustrated by diagrams, and created considerable discussion.

The third paper was by Mr. **Stansbury Hagar,** entitled THE WATER BURIAL. Mr. Hagar paid particular attention to the evidences of water burial as seen among the Micmac Indians, and gave a brief survey of similar customs in all parts of the world, present and past.

The last paper was by Mr. **A. Kroeber,** entitled REMARKS ON THE ESKIMOS OF THE CUMBERLAND SOUND. In this paper Mr. Kroeber compared certain tales of the Eskimos of Cumberland Sound with those of other Eskimos, and paid particular attention to two or three tales which were of unusual interest because of their variations from the ordinary myths as hitherto known among the Eskimos.

Section adjourned at 10 P. M.

RICHARD E. DODGE,
Secretary.

SUBSECTION OF PHILOLOGY.

NOVEMBER 28, 1898.

The meeting was called to order at 8:30 P. M., by the Chairman, Professor McLouth.

The first paper was by Professor **C. L. Speranza,** entitled MACHIAVELLI. Machiavellism in the odious sense generally attributed to the word, is misleading and does great injustice to Machiavelli. It originated in the fact that no notice was taken of the great man's works except the one "Del Principe," which, moreover, was misunderstood and judged from the standpoint of morals instead of that of logic and science, as it ought. The great aim of the booklet, namely, the formation of a great Italian state, founded on the universal consent of the people, finding its legitimacy within itself, independent, autonomous, and defended not by mercenary soldiers, but by its own citizens, was lost sight of. All importance was attached to what immoral means the author, prompted by experience, proposed as best fitted to obtain that aim ; and none whatever was given to the sound and, in some capital respects, original theory set down by him, according to which the ruler of a state must act exclusively as the representative of that state, propose to himself no other object than the good of it, ascertain the best means to accomplish it, and apply these means intelligently and resolutely. While Machiavelli was convinced that the task of forming a great Italian state capable of preserving its independence could be carried out only by one man, and not by a republic, he was also convinced that it was for the people to consolidate and make fruitful the work performed by the one man. But the coiner of the word Machiavellism took no notice of this ; he ignored absolutely Machiavelli's "Discors," by which he taught the people how to govern themselves, and in which he devised the program of democratic government which is entirely modern. Nor was any notice taken of the other fact that Machiavelli proclaimed the necessity of an international code regulating the conduct and results of war, as well as other mutual relations between states ; or of the foundation laid by him upon which the philosophy of history has in modern times been built ; or of the thoroughly experimental method by which he arrived at his conclusions ; or the blow inflicted by him upon the artificial literary form of his days, and the inauguration of the ordinary, direct, natural way of discourse. In fact, Machiavellism, in its generally accepted significance, represents what in Machiavelli's system was merely transitory and dependent upon circumstances of place and time, instead of representing what was original, characteristic and of permanent value.

The second paper was by Professor **A. Cohn,** entitled SOME REFORMS IN FRENCH SPELLING. The needed reforms in French spelling are those that consist in introducing more uniformity, and correcting mistakes that have crept in through misapprehension. In the word *legs* (legacy), for instance, the *g* was introduced, in the sixteenth century, by grammarians who thought this word came from the verb *léguer*, while it really comes from *laisser* (to leave), a good reason for not pronouncing the *g*.

The most important reform needed is the substitution of *s* for *x* in the plural, words like *chapeaux*, and in masculine adjectives like *généreux*, and, in general, at the end of all words where *ux* is preceded by a vowel. The presence of the *x* in these words is the result of a misapprehension; in old French texts the letter *x* is there for *us*, as shown by the interchangeable spellings in the same texts (for instance, *biax*, *biaus* are both found in *Aucassin et Nicolette*). We see thus that in the spelling *dieux*, the letter *u* is really twice represented. The advantage of spelling, in the plural *dieus*, *chapeaus*, and, in a whole class of adjectives, *généreus*, *odieus*, etc., is evident. Besides being a correction, it would simplify greatly the rules for the formation of the plural of nouns and adjectives, and of the feminine of adjectives, as well as the rules of pronunciation. The rule for the formation of the plural of nouns and adjectives in *au*, *eu*, *ou*, would then simply be the general rule: add an *s* to the singular. The rule for the formation of the feminine of adjectives like *généreus*, etc., would also be the general rule: add a mute *e* to the masculine.

Also why spell *nez* (nose) with *z*? This word comes from the Latin *nasum*, and in old French texts *z* stands for *ts*. Etymology would rather require to spell *nez* (Lat. *natos*) and *nés* (Lat. *nasum*), but, of course, no one thinks of substituting *nez* for *nés* in the participle.

Silent penultimate letters like *p* in *corps*, *temps*, might be dropped, and one might also spell *chanbre* instead of *chambre*, substituting *n* for *m* before *b* and *p*, a spelling that would bring more uniformity in the representation of nasal sounds. The Latin origin of these words would be just as clear to scholars as before.

None of these reforms, however, ought to be considered necessary, except the substitution of *s* for *x*, as above outlined.

This last ought to be introduced at once, for the present spelling is perfectly absurd. This paper was discussed by Professor Jackson.

Professor **E. G. Sihler** then read the third paper, on THE MAIN LINES OF CICERO'S POLITICAL JUDGMENTS. Dr. Sihler was led to comment upon Mommsen's attitude toward Cicero and he endeavored to show from history and from Cicero's writings that the Roman orator's judgments of Cæsar were absolutely fair. Professor Sihler went on to show that Cicero actually had a definite policy, that he put himself on the conservative side as opposed to the tribunal or democratic party, and that such were his ideals and such the true convictions that he lived up to in his career. The paper was discussed by Professor Cohn.

The subsection then adjourned.

A. V. WILLIAMS-JACKSON,
Secretary.

REGULAR BUSINESS MEETING.

DECEMBER 5, 1898.

Academy met at 8 P. M., President Osborn in the chair.

Minutes of the last meeting were read and approved.

The following list of nominations were submitted from the Council, recommended for election as resident members, and the Secretary was authorized to cast a ballot for the list and they were thereby elected :

RESIDENT MEMBERS ELECTED.

Rev. A. B. Kendig, 86 Vernon street, Brookline, Mass.
Daniel C. Beard, 204 Amity street, Flushing, L. I.
B. Talbot B. Hyde, 82 Washington street. Life member.
J. D. Irving, Columbia University.
Graham Lusk, New York University Hospital and Medical College.
Marshall A. Howe, Columbia University.
Dr. L. H. Reuter, Merck Building, New York City.
Mason A. Stone, 20 East 66th street.
M. H. Beers, 408–410 Broadway.
Dr. Ivan Sickles, 17 Lexington avenue.
Alfred Douglas, 170 West 59th street.

Dr. Max Meyer, 159 West 103d street.
William L. Mason, 170 Fifth avenue.
William Wicke, First avenue and 31st street.
Edward R. Hewitt, 119 East 18th street.
Charles H. Judd, New York University.
Fred W. Franklin, 700 West End avenue.
John I. D. Bristol, 1 Madison avenue.
Rudolph Keppler, 28 West 70th street. Life member.

The proposed by-laws, submitted to the Academy for adoption, were adopted with two slight amendments, and will appear printed in ANNALS, Vol. XII, No. 1.

After certain announcements by the Secretary in reference to new plans, the Academy adjourned.

RICHARD E. DODGE,
Secretary.

SECTION OF ASTRONOMY AND PHYSICS.

DECEMBER 5, 1898.

The meeting was called to order at 8:15 P. M. by the Chairman, Mr. P. H. Dudley; 24 members and guests being present. The minutes of the last meeting were read and approved.

Mr. **Wallace Goold Levison** presented a paper A SYSTEM OF CLASSIFICATION OF THE FLUORESCENT AND PHOSPHORESCENT SUBSTANCES, in which he classified as phosphorescent all those substances that give out rays of shorter wave-length than that of the rays they have previously received; and as fluorescent, all those substances that give out rays of greater wave-length than those they have received. The system was amplified by an arrangement of substances under headings with reference to the circumstances under which they phosphoresced or fluoresced. The classification was very clearly shown by lantern slides of charts on which all phosphorescent and fluorescent substances were set down, and in addition, remarks about their behavior under various circumstances. This classification has required much labor for its preparation, and at the conclusion of the paper the members of the Section expressed their appreciation of it in a few remarks, with especial reference to the logical arrangement of the subject-matter.

There being no further business, the Section adjourned at 9:50 P. M.

R. GORDON,
Secretary.

SECTION OF BIOLOGY.

DECEMBER 12, 1898.

Thirty-one persons present, Professsor Lee in the chair. The following programme was offered :

1. **F. S. Lee.** THE COURSE OF MUSCLE FATIGUE.
2. **W. K. Brooks.** THE EMBRYOLOGY OF LUCIFER.
3. **F. E. Lloyd.** STUDIES IN THE EMBRYOLOGY OF THE RUBIACEÆ.
4. **N. R. Harrington** and **Edward Leaming.** THE REACTION OF AMŒBA TO LIGHT OF DIFFERENT COLORS.

Professor **Lee** showed that in the different types of animals studied by him in determining the course of muscle fatigue, the height of the curve, which represents the lifting power, becomes less and less in all cases. The reduction in height of the curve is accompanied in the case of muscles from the frog and turtle, by a concomitant increase of the duration of relaxation. The duration of contraction is also increased slightly in the frog and greatly in .the turtle. In the cat neither of these secondary phenomena is represented, the height of the curve, or the lifting power, alone varying. The experiments show that the diminution of the latter phenomenon is the essential element in fatigue.

Professor **Brooks** gave a brief review of his interesting observations on the development of *Lucifer* bringing out in particular the essential features of cleavage and gastrulation which distinguish this decapod from most of its allies.

In the discussion which followed the paper it was shown by Professor Brooks that his results on the unusual mode of cleavage of this form throw no light upon its phylogenetic position or upon that of its allies.

Professor Brooks' paper was accompanied by a demonstration of three microscopic preparations.

Professor **Lloyd** showed that in a number of genera of Rubiaceæ studied by him the embryo-sac is divided into two regions; an upper region in which the pro-embryo is developed, and a lower part containing numerous nuclei of uncertain origin. The suspensor of the pro-embryo develops branches which act as haustoria, taking food from the endosperm. The latter in turn takes its food from the integument by means of cells specialized for food absorption.

Dr. **Leaming** showed that light of different colors acts strongly upon the activities of *Amœba proteus.* Certain colors (red, orange, yellow and green) accelerate the protoplasmic flow, while other colors (white, violet and blue) retard it. The apparatus was fully described and the experiments were repeated in part, before the Section.

GARY N. CALKINS,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

DECEMBER 19, 1898.

Section met with Professor J. F. Kemp in the chair. Twelve persons present.

A paper was read by Mr. **Henry S. Washington,** on THE IGNEOUS ROCKS OF ESSEX COUNTY, MASS. The rocks were described in some detail, and shown to be mainly Granites, Quartz-Syenites corresponding to the Akerites and Nordmarkites of Brögger; Quartz-Diorites and Diorites, with smaller areas of Nepheline-Syenite, Syenite, Essexite and Gabbro. These are cut by numerous dykes of various kinds, including Aplites, Granite-Porphyries, Paisanites, Solvbergites, Tinguaites, and many basic dykes, most of which are of Diabase, but some of camptonitic rocks. There are also extensive flows of Rhyolite, accompanied by ash beds and breccias. Twenty-two analyses of the various types were given.

The character of the region as a petrographical province was discussed at some length. Chemically it was shown to be rich in alkalies, especially Soda, low in Lime and very low in Magnesia, and rather acid. The low Magnesia was commented on, and the occurrence noted of many minerals in these rocks as varieties poor in this oxide which are usually rich in it, as Lepidomelane, Fayalite and Glaucophane. The usually high ratio of FeO to Fe_2O_3 was discussed and it was pointed out that in most of the rocks FeO is extremely high, replacing MgO, while in the foyaitic group it is much lower. Iron oxides tend to vary with soda. Soda is constantly higher than Potash, but the molecular ratio varies a great deal, being about 1.10 in the granitic rocks, higher in the foyaitic group, and very high in the basic, the ratio in nearly every case approximating to whole numbers. This differentiation of Na_2O was commented on and its importance pointed out.

Comparisons were instituted with other regions and the great resembance to the rocks of southern Norway were described. It was shown that probably the chemical composition of the magma as a whole approaches that of a Nordmarkite, and that it is rather acid, as in Norway. The relations of the rocks of Essex county to those of the other alkali-rich regions of the Atlantic slope were also discussed.

The paper was discussed by Professor Kemp and others.

A. A. JULIEN,
Secretary pro tem.

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APPENDIX.

NEW YORK

ACADEMY OF SCIENCES.

Fifth Annual Reception

and Exhibit of

Recent Progress in Science

in the

American Museum of Natural History,

April 13 and 14,

1898.

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April 13.

Reception to Members of Academy and
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April 14.

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Evening Reception, to Members of the
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Demonstrative Address, "The Function
of Large Telescopes," Promptly at - 9 p. m.
By Prof. Geo. E. Hale.

Preceded by an

Introduction by the President of the Academy,
Prof. Henry F. Osborn.
and by the President of the Museum
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A

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2. THE STRUCTURE OF THE FOURTH VENTRICLE AND OF THE LATERAL RECESSES. Exhibited by Dr. Jos. A. Blake.
3. RECENT STUDIES IN THE VISCERAL ANATOMY AND THE VASCULAR SYSTEM OF REPTILIA. Exhibited by the Department of Anatomy, Columbia University.
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B

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   - *a.* Vicinity of Eta Carinæ, photographed with the Bruce telescope.
   - *b.* Large Magellanic Cloud.
   - *c.* Arequipa Station, showing new Bruce Building.
   - *d.* Bruce Building.
   - *e.* Spectroscopic Binary, μ' Scorpii.
   - *f.* Spectroscopic Binary, A. G. C. 10534.

g. Spectrum of ξ Puppis.
h. Spectrum of Meteor as photographed.
i. Spectrum of Meteor, enlarged 9 times.
j. Variations in Light of U Pegasi.
k. Proper Motion of Z. C. 5h 243 and occultation of 26 Arietis.
l. Dumbbell Nebula.
m. Spiral and Ring Nebulæ.
n. Nebula in Andromeda.

2. PHOTOGRAPHS OF APPARATUS AND OF STELLAR SPECTRA, ILLUSTRATING A NEW METHOD. Exhibited by Prof. Charles Lane Poor, of Johns Hopkins Observatory.
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b. Concave grating spectroscope; direct form.
c. Same as *b*, mounted on telescope.
d. Series of spectra of Sirius, including Glass positive, ordinary size; photograph enlarged three times without widening; photograph, enlarged and widened; Glass positive, enlarged and widened; Series of Spectra of other stars.

3. CHARTS AND SKETCHES. Exhibited by United States Coast and Geodetic Survey, H. S. Pritchett, Superintendent, Washington, D. C.
a. Isogonic and Isoclinic Charts for 1900 A. D.
b. Base map showing astronomical positions and gravity stations to date.
c. Sketch showing the Triangulation of the Great Transcontinental arc from Cape May, New Jersey, to Point Arena, California.

4. GLASS POSITIVES. Exhibited by the Yerkes Observatory of the University of Chicago, George E. Hale, Director.
a. Photographs of the Building and Instruments of the Yerkes Observatory. Thirty positives on glass.
b. Stellar spectra photographed with the 40-inch telescope and stellar spectographs by Hale.

1. Part of spectrum of *α* Orionis (three prisms).
2. Part of spectrum of *o* Citi (Mira)—(three prisms).
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5. BROMIDE ENLARGEMENTS OF PHOTOGRAPHS OF RECENTLY CONSTRUCTED INSTRUMENTS. Exhibited by Warner & Swazey, Cleveland, Ohio.
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7. MIRRORS AND REEL USED IN THE DETERMINATION OF THE CONSTANT OF ABBERRATION BY THE LOEWY METHOD. Exhibited by Professor George C. Comstock, Washburn Observatory, Madison, Wis.

C

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11. DEVELOPMENT OF THE EMBRYO SAC IN SAGITTARIA. Exhibited by Miss Louise B. Dunn.

12. NEW JAPANESE AND AMERICAN CHARACEÆ. With illustrations and descriptions. Exhibited by Dr. T. F. Allen.

13. NEW SPECIES FROM THE VICINITY OF NEW YORK CITY. Illustrated by Specimens. Exhibited by Mr. Eugene P. Bicknell.

14. TWO NEW SANICULAS FROM THE SOUTHERN STATES. Represented by specimens. Exhibited by Mr. Eugene P. Bicknell.

15. MOSSES OF NORTHERN BOLIVIA AND SOUTHERN PERU. Collected by Pierre Jay in July and October, 1893. Exhibited by Elizabeth G. Britton.

16. SOME NEW SPECIES OF ASTER. Exhibited by Prof. Edward S. Burgess.

17. SPECIMENS AND FIGURES ILLUSTRATING THE HEPATIC FLORA OF CALIFORNIA. Exhibited by Mr. Marshall A. Howe.

18. NEW SPECIES IN THE GRAMINEÆ. Illustrated by specimens. Exhibited by Mr. Geo. V. Nash.

19. TWO NEW GRASS GENERA. Illustrated by specimens. Exhibited by Mr. Geo. V. Nash.

20. NEW GENERA AND SPECIES OF PLANTS FROM SOUTH AMERICA. Exhibited by Dr. H. H. Rusby.

21. NEW SPECIES FROM MONTANA. Exhibited by Mr. P. A. Rydberg.

22. NEW SPECIES IN THE SOUTHERN UNITED STATES. Illustrated by specimens. Exhibited by Dr. John K. Small.

23. RECENT DISCOVERIES IN THE GENUS ERIOGONUM. Illustrated by specimens. Exhibited by Dr. John K. Small.

24. TWO NEW GENERA FROM NORTH AMERICA. Exhibited by Dr. John K. Small.

25. SPECIMENS REPRESENTING RECENT RESEARCH IN THE ASCLEPIADACEÆ. Exhibited by Miss Anna Murray Vail.

26. NEW SPECIES FROM NEW MEXICO. Exhibited by Mr. E. O. Wooton.

27. A FOSSIL MOSS FROM THE TERTIARY, PROBABLY MIOCENE, OF THE STATE OF WASHINGTON. Collected near Cle Elum, Kittetass Co., by Mr. I. C. Russell, July 7th, 1897. Exhibited by Dr. F. H. Knowlton, Elizabeth G. Britton and Dr. Arthur Hollick.

28. SOME STUDIES ON THE BACTERIOLOGY OF THE NEW YORK CITY WATER SUPPLY. Exhibited by Smith Ely Jelliffe, M.D., F. G. Kneer, M.D., and O. Hensel, Ph.G.

NOTE.—The more important botanical publications of members during the year are exhibited on a table and are open to examination.

D

CHEMISTRY.

IN CHARGE OF CHARLES A. DOREMUS.

1. LIQUID AIR WITH EXPERIMENTAL ILLUSTRATIONS OF ITS PROPERTIES. Exhibited by Mr. Charles E. Tripler.
2. BOMB CALORIMETER. Exhibited by Dr. H. W. Wiley, Chief of Division of Chemistry, United States Department of Agriculture.
3. IMPROVED SPECIFIC GRAVITY BOTTLES OR PYKNOMETERS. Exhibited by Dr. E. R. Squibb.
4. IMPROVED ZERO BURETTE. Exhibited by Dr. E. R. Squibb.
5. VISCOSIMETER. Exhibited by Mr. P. H. Conradson.
6. PROGRESS IN MANUFACTURE OF ARTISTIC GLASS. Exhibited by Mr. Louis C. Tiffany.
7. SPECIMENS OF TRITHIOFORMALDEHYDE, TRITHIOALDEHYDE AND ANHYDROFORMALDEHYDE-ANILIN; SODIUM OXYMETHYLSULFONATE, TRIOXYMETHYLENE AND SALIFORMIN. Exhibited by Dr. L. H. Reuter.
8. SPECIMENS OF SALICYLID, SALICYLIDCHLOROFORM AND POLYSALICYLID. Exhibited by Dr. L. H. Reuter.
9. TABLES TO SHOW THE APPLICATION OF THE PERIODIC SYSTEM TO THE STUDY OF ANALYTICAL METHODS. Exhibited by Professor Robert W. Hall.
10. MODELS INDICATING THE RELATION BETWEEN VOLUME, PRESSURE AND TEMPERATURE OF GASES. Exhibited by Professor Morris Loeb.
11. PURE PREPARATIONS OF TELLURIUM AND SOME OF ITS COMPOUNDS. Exhibited by Professor Morris Loeb and Mr. J. H. Shipley.
12. ARTIFICIAL CRYSTALS OF CHEMICAL COMPOUNDS, ILLUSTRATING ISOMORPHISM AND ENANTIOMORPHISM. Exhibited by the Chemical Museum of New York University.

13. **Exhibits from the laboratory of Columbia University** by Professor C. E. Pellew and Dr. S. A. Tucker.
    - *a.* Calico Printing. The production of insoluble azo colors in the cotton fibre.
    - *b.* Viscose. Exhibition of Process and Samples of the new form of Soluble and Amorphous Cellulose known as Viscose.
    - *c.* Electrochemistry. The Persulphates and Percarbonates of Alkaline Metals, Prepared by Electrolysis of the Normal Salts.

14. **Exhibits from the Laboratory of the College of the City of New York.**
    - *a.* Three different types of ray filters to contain either liquids or gases and suitable for photographic or purely chemical work. Exhibited by Dr. L. H. Friedburg.
    - *b.* Red sublimate of Nitro-diphenylamin and Yellow crystals of quinone-oxim. Exhibited by Dr. L. H. Friedburg.

E

ELECTRICITY.

In Charge of Geo. F. Sever.

1. **Exhibit of new Apparatus** by Queen & Co. through Mr. O. T. Louis.
    - *a.* Horizontal Magnet D'Arsonval Galvanometer.
    - *b.* A new Automatic Self-Focusing Arc Lamp.
    - *c.* Acme Testing Set.
    - *d.* A complete 12" X-Ray Outfit with Self-Regulating Tube.
    - *e.* A new Lantern Galvanometer.
    - *f.* A new Portable Photometer.
    - *g.* A new Portable Cable Testing Galvanometer.

2. AMERICAN APPARATUS FOR THE TRANSMISSION OF SIGNALS AT A DISTANCE WITHOUT WIRES. MARCONI SYSTEM. Exhibited by Mr. W. J. Clarke.
3. EXHIBIT OF NEW ELECTRICAL APPARATUS by Prof. M. I. Pupin.
   - *a.* Optical Telephone.
   - *b.* Induction Coil with 30″ spark.
   - *c.* Electrical Oscillators for Selective Signalling.
   - *d.* Bridge for measuring phase retardation between current and electro-motive force.
4. METHOD OF SUPPORTING GALVANOMETERS TO AVOID VIBRATIONS. Exhibited by Electrical Engineering Department, Columbia University.
5. EXHIBIT OF RECENT ELECTRICAL APPARATUS by Mr. J. G. Biddle.
   - *a.* 1898 Type Willyoung Induction Coil.
   - *b.* Willyoung Direct Reading Potentiometer.
   - *c.* The Rowland Electro Dynamometer.
   - *d.* The Rosa Curve Tracer for Alternating Current Curves.

F

ETHNOLOGY AND ARCHÆOLOGY.

IN CHARGE OF FRANZ BOAS AND L. FARRAND.

1. EXHIBIT OF THE JESUP NORTH PACIFIC EXPEDITION.
   - *a.* Facial paintings of Indians of the North Pacific Coast. Collected by F. Boas and L. Farrand.
   - *b.* The Prehistoric Races of southern British Columbia. Collected by Harlan I. Smith.
   - *c.* Conventionalism among the Thompson River Indians. Collected by James Teit.
2. SYMBOLISM OF THE HUICHOL INDIANS OF MEXICO. Collected by Dr. Carl Lumholtz and exhibited by the American Museum of Natural History.

EXPERIMENTAL PSYCHOLOGY.

IN CHARGE OF CHARLES B. BLISS.

1. AN AUTOMATOGRAPH WITH REGISTRATION ATTACHMENTS. Exhibited by Mr. W. L. McWhood.
2. AN INSTRUMENT FOR STUDYING THE DISCRIMINATION OF LOUDNESS OF SOUNDS. Exhibited by Prof. J. McKeen Cattell.
3. AN INSTRUMENT FOR THE MEASUREMENT OF THE TIME OF PERCEPTION AND MOVEMENT. Exhibited by Prof. J. McKeen Cattell.
4. VERNIER CHRONOSCOPE. Exhibited by Prof. Edmund C. Sanford.
5. AN AUDIOMETER. Designed by Dr. J. A. Gilbert and exhibited by Prof. Charles B. Bliss.
6. AN ADJUSTABLE STEREOSCOPE CARD. Exhibited by Prof. Charles B. Bliss.

H

GEOLOGY.

IN CHARGE OF ARTHUR HOLLICK.

1. SUITE OF EUROPEAN CLAYS AND KAOLINS AND OBJECTS SHOWING CLAY WHEN BURNED. Collected and exhibited by Dr. Heinrich Ries.
2. BAUXITES FROM DEPARTMENT OF HERAULT IN SOUTHERN FRANCE. Obtained and exhibited by Dr. Heinrich Ries.
3. COPPER ORES AND ACCOMPANYING ROCKS, FROM OTTO SHAFT, EISLEBEN, NEAR MANSFIELD, GERMANY. Collected and exhibited by Dr. Heinrich Ries.
4. SPECIMENS FROM THE SALT MINES, STAASFURT, GERMANY. Collected and exhibited by Dr. Heinrich Ries.

5. FULLER'S EARTH FROM ENGLAND. Collected and exhibited by Dr. Heinrich Ries.

6. BAUXITE FROM STYRIA, AUSTRIA. Exhibited by Dr. Heinrich Ries.

7. SPECIMENS SHOWING TRANSITION FROM QUARTZ-PORPHYRY TO KAOLIN FROM DÖLAN, NEAR HALLE, GERMANY. Collected and exhibited by Dr. Heinrich Ries.

8. FULGURITE. Summit of Little Ararat, Russian Armenia. Collected by Dr. E. O. Hovey, Sept. 30, 1897. Exhibited by Dep't of Geology, of American Museum of Natural History.

9. GRANITES AND GNEISSES FROM FINLAND. Exhibited by Professor J. J. Stevenson.

10. ORES AND ROCKS FROM PELICAN AND DIVES MINES, GEORGETOWN, COLO. Exhibited by Professor J. J. Stevenson.

11. PHOTOGRAPHS AND SPECIMENS ILLUSTRATING RECENT EXPERIMENTS IN PRODUCING COMPRESSIONS AND FLOWAGE OF MARBLE WITHOUT RUPTURE OR DESTRUCTION OF COHESION. Exhibited by Dr. F. D. Adams, Mc. Gill University, Montreal.

12. SUITE OF ROCK SPECIMENS ILLUSTRATING THE RECENT PETROLOGICAL WORK OF PROFESSOR W. C. BRÖGGER, IN THE VICINITY OF KRISTIANIA, NORWAY. Exhibited by Henry S. Washington, Locust, N. J.

13. SUITE OF ROCK SPECIMENS ILLUSTRATING RECENT PETROLOGICAL WORK OF THE EXHIBITOR UPON THE LEUCITIC AND TRACHYTIC ROCKS OF THE ITALIAN PENINSULA. Exhibited by Henry S. Washington, Locust, N. J.

14. EXHIBITION OF MODELS AND SPECIMENS by Professor J. F. Kemp, Columbia University.
    a. Model of the Franklin Furnace Zinc Ore-body, made by F. L. Nason for the Lehigh Zinc Co.

b. Suite of gold-bearing conglomerates from the so-called "banket" reefs, near Johannesburg, South African Republic. Collected by Mr. J. T. Curtis.

c. Specimen illustrating the cross-section of a tin-bearing pegmatite vein, Saxony.

d. Specimen illustrating the cross-section of the Half-moon vein, Pioche, Nevada, collected by Mr. George W. Maynard.

e. Model illustrating the Black Rock silver vein, Butte, Mont., secured through the courtesy of Mr. W. D. Thornton.

15. GEOLOGICAL MODEL OF NANTUCKET ISLAND. Exhibited by the designer and maker, George C. Curtis.

16. MODEL OF NEW YORK ISLAND. Colored as to Geology and exhibited by Dr. F. J. H. Merrill, of the New York State Museum.

17. SERIES OF GEOLOGICAL MAPS SHOWING RECENT PUBLISHED RESULTS IN THE UNITED STATES GEOLOGICAL SURVEY, AND EXHIBITED BY THE SAME.

a. Pyramid Peak and Truckee, areal sheets.

b. Franklin, Va., areal, economic and structure sheets.

c. Wartburg and Briceville, Tenn., areal and economic.

d. Peublo, Col., 8 sheets.

e. Butte Special, Mont., topographic and economic.

18. SET OF SPECIMENS. Exhibited by Professor R. E. Dodge, of Teachers College.

a. Fault breccia from the Quarry Bed, Meriden, Conn.

b. Cinders from the Ash Bed, Lamentation Mountain, Meriden, Conn.

c. Strain slip cleavage from Wallingford, Vt.

19. A SERIES OF ANDESITES, BASALTS, TUFFS, ETC., FROM THE ANTI-CAUCASUS MOUNTAINS AND RUSSIAN ARMENIA, collected in September–October, 1897, by E. O. Hovey, and exhibited by the Geological Department, American Museum of Natural History.

MINERALOGY.

IN CHARGE OF EDMUND O. HOVEY.

1. PETROGRAPHIC INSTRUMENTS. Exhibited by the inventor, Dr. T. A. Jaggar, Jr., Harvard University.
   - *a.* Microsclerometer, for determining exactly the hardness of minerals under the microscope.
   - *b.* Instrument for inclining a preparation in the petrographic microscope.

2. MODELS AND APPARATUS recently acquired by the Mineralogical Department, Columbia University, and exhibited by Prof. A. J. Moses.
   - *a.* Student Goniometer designed by Prof. P. Groth.
   - *b.* Model of Spherical Projection, Isometric Crystal.
   - *c.* Model of Spherical Projection, Triclinic Crystal.
   - *d.* Model of Positive Uniaxial Ray Surface.
   - *e.* Model of Negative Uniaxial Ray Surface.
   - *f.* Model of Biaxial Ray Surface.

3. EXHIBIT OF PROF. J. F. KEMP, COLUMBIA UNIVERSITY.
   - *a.* Chalcanthite, Mt. Wilson, San Miguel County, Colo. Collected by M. B. Spaulding.
   - *b.* Calaverite (?), inclosing Native Gold, Kalgoorlie, Westralia. Collected by G. J. Bancroft.

4. EXHIBIT OF THE DEPARTMENT OF MINERALOGY, AMERICAN MUSEUM NATURAL HISTORY, through L. P. Gratacap.
   - *a.* Endlichite, Hillsboro, New Mexico.
   - *b.* Pollucite, Paris, Maine.
   - *c.* Hamlinite, Paris, Maine.
   - *d.* Montmorillonite, Paris, Maine.
   - *e.* Beryl, containing cæsium, Haddam Neck, Conn.
   - *f.* Microcline, Haddam Neck, Conn.

5. EXHIBIT OF PROF. S. L. PENFIELD, YALE UNIVERSITY.
   - *a.* Wellsite, Buck Creek, Clay County, N. C.
   - *b.* Bixbyite, on Topaz, Near Simpson, Utah.
   - *c.* Clinohedrite, Franklin, N. J.
   - *d.* Illustrations of some methods for mounting crystals.

6. EXHIBIT OF LAZARD CAHN, NEW YORK.
   - *a.* Herderite, Auburn, Maine.
   - *b.* Hamlinite, Oxford County, Maine.
   - *c.* Pollucite, Oxford County, Maine.
   - *d.* Montmorillonite, Oxford County, Maine.

7. EXHIBIT OF ERNEST SCHERNIKOW, BROOKLYN.
   - *a.* Tourmaline Crystals and cross sections, Haddam Neck, Conn.
   - *b.* Beryl, Haddam Neck, Conn.
   - *c.* Microcline, with muscovite and lepidolite, Haddam Neck, Conn.

8. EXHIBIT OF DR. A. E. FOOTE, WARREN M. FOOTE, MANAGER, PHILADELPHIA.
   - *a.* Crocoite, Western Tasmania.
   - *b.* Massicot, Western Tasmania.
   - *c.* Cerussite, Western Tasmania.
   - *d.* Gmelinite, Flinders, Victoria, N. S. W.
   - *e.* Mesolite, Flinders, Victoria, N. S. W.
   - *f.* Vivianite, Falls of Wannon River, Victoria.
   - *g.* Ferrocalcite, Near Melbourne, Victoria.
   - *h.* Phillipsite, Near Melbourne, Victoria.
   - *i.* Phacolite, Near Melbourne, Victoria.
   - *j.* Newberyite, Skipton Caves, near Ballarat, Victoria.
   - *k.* Stephanite, Lake Chelan District, Montana.
   - *l.* Endlichite, Hillsboro, New Mexico.
   - *m.* Marcasite, Near Sparta, Ill.
   - *n.* Roeblingite, Franklin Furnace, N. J.
   - *o.* Meteoric Iron (section), Sacramento Mountains, Eddy County, N. M.

9. EXHIBIT OF GEORGE F. KUNZ, NEW YORK.
   - *a.* Celestite, Put-in-Bay, Ohio.

b. Meteoric Iron, York County, Nebraska.

c. Sapphire Crystals, Yogo Gulch, Fergus County, Montana.

d. Rutilated Quartz, sphere 5½ inches in diameter, New Zealand. The property of the Tiffany Co.

e. Quartz (Rock Crystal), Mac Elumne Hill, Calaveras County, Calif.

f. Tourmaline, Smoky Quartz and Graphic Granite, Mt. Mica, Paris, Me.

10. EXHIBIT OF A. CHESTER BEATTY, NEW YORK.
Calaverite, Cripple Creek, Colo.

PALÆONTOLOGY.

IN CHARGE OF GILBERT VAN INGEN.

1. CAUDAL VERTEBRÆ AND LIMB BONES OF THE GIGANTIC DINOSAUR CAMARASAURUS, COPE, BRONTOSAURUS, MARSH. Exhibited by Professor Henry F. Osborn, Department of Vertebrate Palæontology, American Museum of Natural History.
2. CAUDAL VERTEBRÆ AND LIMB BONES OF DIPLODOCUS, MARSH. Exhibited by Prof. Henry F. Osborn, of the Department of Vertebrate Palæontology, American Museum of Natural History.
3. SERIES OF FEET AND SKULLS, ILLUSTRATING THE EVOLUTION OF THE CAMELS AND LLAMAS IN NORTH AMERICA. Exhibited by Dr. J. L. Wortman, Department of Vertebrate Palæontology, American Museum of Natural History.
4. SKELETONS OF THE EARLIEST AMERICAN UNGULATES—PANTOLAMBDA AND EUPROTOGONIA. Exhibited by Dr. W. D. Matthew, Department of Vertebrate Palæontology, American Museum of Natural History.
5. RESTORATIONS OF EXTINCT REPTILES AND MAMMALS. Seven large water colors exhibited by Chas. Knight, Department of Vertebrate Palæontology, American Museum of Natural History.

6. MODELS OF EXTINCT VERTEBRATES by Chas. Knight, cast by Jacob Gommel. Exhibited by the Department of Vertebrate Palæontology, American Museum of Natural History.

7. SERIES OF EXHIBITS by Dr. Chas. R. Eastman, of Harvard University.
   - *a.* Fin of new species of Cladodont Shark, from the Hamilton group, near Buffalo, N. Y.
   - *b.* Photograph of Egg of Ostrich, *Struthiolithus chersonensis*, Brandt., from superficial (Pleistocene) deposits, northern China.
   - *c.* Photograph showing variation in Dental Plates of the Chimæroid, *Ptyctodes calcolus* N. & W., from the Devonian of Iowa.
   - *d.* Photograph of the remarkable Psammodont-Cochliodont-Lung-fish, *Synthetodus*. From the Upper Devonian (State Quarry) Fish-bed, Johnson Co., Iowa.

8. EXHIBIT IN PALÆOBOTANY by Mr. Arthur Hollick, of Department of Geology, of Columbia University.
   - *a.* Fossil Plants from the Middle Cretaceous clays of Block Island, R. I.
   - *b.* Samples of the Plant Bearing Basal clays, Middle Cretaceous, and the Superficial Bowlder-clays, Glacial, of Block Island, R. I.
   - *c.* A new fossil Palm from the Yellow Gravel (Miocene ?) of Bridgeton, N. J.

9. NEW FOSSIL FUNGI, PRESERVED IN SILICIFIED WOOD AND EXHIBITED UNDER THE MICROSCOPE, by Dr. A. A. Julien, Department of Geology, Columbia University.
   - *a.* In wood of the Petrified Forest, at Chalcedony Park, Arizona.
     1. Silicified fungus-spore, in act of sprouting.
     2. Silicified bacteria. A chain of bacilli crossing limpid quartz.
     3. Silicified mycelium, branching along the walls of the wood-cells, and secreting iron-oxide.

b. In wood of the Petrified Forest, near Cairo, Egypt.
   1. Young sporanges on walls of the wood-cells.
   2. Mature sporanges, enclosing spores.
   3. Chain of sporanges.

K

PHILOLOGY.

IN CHARGE OF LAWRENCE A. MCLOUTH AND A. V. WILLIAMS JACKSON.

The exhibits in each language will represent all or part of the following heads:

1. MANUSCRIPTS.
2. FACSIMILES OF MANUSCRIPTS.
3. EDITIONS—OLD, RARE, OR NEW.
4. LEXICAL AND GRAMMATICAL WORKS.
5. ILLUSTRATIVE MATERIAL: PHOTOGRAPHS, ENGRAVINGS, AUTOGRAPH LETTERS, ARCHÆOLOGICAL REMAINS.
6. JOURNALS AND PERIODICALS.

A. PHILOLOGY IN GENERAL.

1. SOME OF THE MORE RECENT WORKS ON THE SUBJECT.
2. CERTAIN RESULTS IN THE FIELD OF DIALECT STUDY IN AMERICA. Exhibited by Mr. E. H. Babbitt, Columbia University (Secretary of American Dialect Society).

B. SPECIAL LANGUAGES AND LITERATURES.

1. INDO-GERMANIC.
   a. Indo-Iranian. With the coöperation of Prof. A. V. Williams Jackson and Mr. A. Yohannan, Columbia University.
   b. Armenian. With the coöperation of Mr. A. Yohannan, Columbia University.

- *c.* Greek. With the coöperation of Professors E. D. Perry and J. R. Wheeler, Columbia University, and Prof. H. M. Baird, New York University.
- *d.* Latin. With the coöperation of Professors E. G. Sihler, New York University, and E. C. Egbert, Columbia University.
- *e.* Romance. With the coöperation of Professors H. A. Todd and A. Cohn, Columbia University, and Prof. W. K. Gillett, New York University.
- *f.* Germanic. With the coöperation of Professors W. H. Carpenter and Calvin Thomas, Columbia University, Prof. L. A. McLouth, New York University, Prof. T. R. Price, Columbia University.

2. SEMITIC.
   - *a.* Hebrew.
   - *b.* Aramaic.
   - *c.* Arabic.

   With the coöperation of Prof. J. D. Prince and Mr. Geo. Osborne, New York University, and Prof. R. J. H. Gottheil, Columbia University.

3. OTHER LANGUAGES.
   - *a.* American Indian. Dr. F. Boas, Columbia University.
     1. An Indian Newspaper. Printed in Shorthand. Edited by Rev. J. M. Le Jeune, Kamloops, British Columbia. Exhibited by Dr. Franz Boas.
     2. Indian Manuscript. Written by a half-blood Indian of Fort Rupert, B. C.
   - *b.* Chinese. With the coöperation of Prof. J. D. Prince, New York University.

L

PHOTOGRAPHY.

IN CHARGE OF CORNELIUS VAN BRUNT.

1. EXHIBIT BY MR. G. GENNERT.
   - *a.* New developer, "Ortol."

- *b.* Zeiss telephoto lense, capable of doing instantaneous work.
- *c.* New Cycle and Hand Camera.
- *d.* New Platini paper—producing Platinotype effects.
- *e.* Series of framed prints, showing the work of Platini-paper.

2. EXHIBITS OF E. & H. T. ANTHONY & CO.
   - *a.* Farrand Vignetter.
   - *b.* New Dalmeyer Stigmatic lense, F. 6th Series, No. II.
   - *c.* Frame of Photographs, illustrating New Dalmeyer Stigmatic lense combinations.
   - *d.* Frame of Photographs, illustrating American Aristotype paper—with new toner.
3. EXHIBIT OF BAUSCH & LOMB OPTICAL CO.
   - *a.* Iconoscopes—Three sizes.
   - *b.* Ray Filters—Styles A and B.
   - *c.* Zeiss convertable, Series VII. A, No. 8.—Lense with diaphragm shutter and telephoto attachment.
   - *d.* Zeiss convertable, lense C, set with diaphragm shutter. All manufactured by the above company.
   - *e.* Photographs, showing effects with and without "Ray filter."
4. THE JOLY-SAMBRA CO., Montclair, New Jersey.
   - *a.* Demonstration of new color process by electric light.
   - *b.* Lantern slides and screens.

M

PHYSICS.

IN CHARGE OF WM. HALLOCK.

1. SET OF PHOTOGRAPHS SHOWING WIDENING OF SPECTRUM LINES WITH INCREASE OF PRESSURE. Exhibited by Prof. J. S. Ames, Johns Hopkins University.
2. PHOTOGRAPHS OF PROJECTION LANTERN. Exhibited by Prof. Le Conte Stevens, Trov, N. Y.

3. BREAK-CIRCUIT ATTACHMENT FOR PENDULUM. Exhibited by Prof. W. Hallock, Columbia University.

4. PENDULUM, ADJUSTABLE PERIOD. Exhibited by Prof. W. Hallock, Columbia University.

5. TORSION PENDULUM OF ADJUSTABLE PERIOD. Exhibited by Prof. W. Hallock, Columbia University.

6. IMPROVED APPARATUS FOR DETERMINING BATTERY RESISTANCE; Mance's method. Exhibited by W. S. Day, Columbia University.

7. PHOTOGRAPHED MICROMETER OCULAR. Exhibited by Wallace Goold Levison.

8. APPARATUS FOR SHOWING PHOSPHORESCENCE. Exhibited by Wallace Goold Levison.

9. STREMMATOGRAPH AND RECORDS. Exhibited by P. H. Dudley.

10. SIMPLE PHOTOSPECTROGRAPH WITH NEGATIVES. Exhibited by F. L. Tufts, Columbia University.

11. BAUSCH & LOMB MICROSCOPE STAND WITH SPECIAL ARM FOR MICROMETRIC MEASUREMENTS. Exhibited by P. H. Dudley.

12. NEW FORM OF THERMOMETER FOR SUBTERRANEAN TEMPERATURE WORK. Exhibited by Prof. W. Hallock, Columbia University.

13. SERIES OF LANTERN SLIDES ILLUSTRATING A NEW METHOD OF COLORING BY WHICH UNIFORMITY OF TINT AND DEFINITION OF OUTLINE IS OBTAINED. Exhibited by C. C. Trowbridge, Columbia University.

14. SET OF SCALES PROVIDED WITH DIFFERENT TYPES OF VERNIER, used in the Physical Laboratory, Columbia University. Exhibited by C. C. Trowbridge and H. S. Curtis, Columbia University.

15. SCHÖNE'S APPARATUS FOR MECHANICAL ANALYSIS, AND SPECIMENS TESTED BY IT. Exhibited by Dr. H. Ries, Columbia University.

16. PORCELAIN MILL FOR GRINDING CLAY AND OTHER SOFT-MINERALS. Exhibited by Dr. H. Ries.
17. SUITE OF SPECIMENS SHOWING SHRINKAGE OF CLAY AT DIFFERENT TEMPERATURES. Exhibited by Dr. H. Ries.
18. AUDIMETER FOR THE MEASUREMENT OF THE SENSITIVENESS OF THE EAR. Exhibited by Prof. Alfred G. Compton, Department Applied Mathematics, College of the City of New York.
19. CALORIMETER FOR LIQUIDS. Exhibited by R. L. Litch, Princeton University.
20. WATERMAN CALORIMETER. Exhibited by Prof. F. A. Waterman, Smith College.
21. SPECIAL ELECTRICAL APPARATUS. Exhibited by J. E. Moore, Princeton University.
22. PHOTOGRAPHS SHOWING THE PENETRABILITY, THE PATH AND THE REFRACTION OF ROENTGEN'S RAYS, by A. Bourgougnon.

N

PHYSIOGRAPHY.

IN CHARGE OF ROBERT H. CORNISH.

1. A SERIES OF THREE MODELS OF TYPICAL LAND FORMS, designed and modeled by Prof. W. M. Davis and G. C. Curtis, and exhibited by the Harvard Geographical Laboratory.
2. A MODEL SHOWING SEA COAST CHARACTERISTICS. Exhibited by the designer, G. C. Curtis.
3. MODEL OF THE STATE OF NEW YORK. Executed under the direction of the New York State Museum, and exhibited by the same, through Dr. F. J. H. Merrill, Director.
4. MODEL OF THE CATSKILL MOUNTAINS. Executed under the direction of the New York State Museum, and exhibited by the same, through Dr. F. J. H. Merrill, Director.
5. MODEL OF NEW YORK ISLAND, SHOWING TOPOGRAPHY IN 1776. Exhibited by the New York State Museum, through Dr. F. J. H. Merrill, Director.

6. Exhibit of Recent Topographic Maps, made and loaned by the United States Geological Survey, Washington, D. C.
   - *a.* Vicinity of Lake George.
   - *b.* Mohawk Valley.
   - *c.* Platte Valley, Nebraska.
   - *d.* Drumlin Area of Wisconsin.
   - *e.* Progress Map, New York and New England,
7. Numbers 36 and 37 of Hölzel's Geographische Charakterbilder. Loaned by the Teachers College.
8. Two Transparencies for Teaching Astronomical Geography. Published by the Century School Supply Co., and loaned by the Teachers College.
9. Panorama of Crater Lake, Oregon. Photographed and exhibited by Prof. F. E. Lloyd, of Teachers College.

Note.—The more recent books in Physiography and the topographic maps of New York State thus far published are exhibited on a table.

O

ZOOLOGY.

In Charge of E. B. Wilson.

1. Illustrations of the Fauna of Bermuda. From collection made in June, 1897, by the New York University Alumni Expedition. Exhibited by Prof. C. L. Bristol.
2. Illustrations of Nemertean and Enteropneustan Fauna of Puget Sound. Exhibited by B. B. Griffin.*
   - *a.* *Carinella sexlineata* n. sp. (fragments).
   - *b.* *Carinoma mutabilis* n. sp. type and var. *argillina* with piece of clay in which latter lives.
   - *c.* *Emplectonema viride* Stimpson (a few individuals from San Francisco, showing lighter hue of written specimens).

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* Owing to Mr. Griffin's death this exhibit could not be prepared.

- *d.* *Cerebratulus marginatus* Renier and *C.* sp.
- *e.* *Amphiporus*, several species.
- *f.* *Ptychodera* sp.

3. PREPARATIONS ILLUSTRATING DEVELOPMENTAL STAGES OF THE CRANIUM AND CLASPING ORGANS IN THE CHIMÆROID, *Hydrolagus colliei.* Material from the Puget Sound expedition of 1896 of the Zoölogical Department of Columbia University. Exhibited by R. W. Shearman.

4. *a.* DEVELOPMENTAL STAGES OF THE AUSTRALIAN LUNG-FISH, *Ceratodus forsteri*, collected near Gayndâh, Queensland.

   b. LARVÆ OF EELS—*Conger*, *Congermuræna*, *Anguilla*—from Strait of Messina. Received through Professor Lankester from Professor Grassi. Exhibited by Dr. Bashford Dean.

5. EFFECTS OF LIGHT OF DIFFERENT COLORS UPON PROTOPLASM. Exhibited by N. R. Harrington and E. Leaming.

6. EXHIBITION OF TEACHING PREPARATIONS by B. B. Griffin. Development stages of:

   a. Petromyzon; *b.* Shark; *c.* Skate; *d.* Lepidosteus; *e.* Accipenser; *f.* Amia; *g.* Amiurus; *h.* Necturus; *i.* Frog; *j.* Lizard.

7. GRAFTING EXPERIMENTS UPON MOTHS. Compound pupæ and compound adult moths, illustrated by photographs and specimens. Exhibited by H. E. Crampton, Jr.

8. SLIDES ILLUSTRATING THE ORIGIN OF NUCLEI IN PROTOZOA. Exhibited by G. N. Calkins.

   - *a.* Monad (*Tetramitus*) with distributed nucleus.
   - *b.* Monad (*Chilomonas*) with intermediate type of nucleus.
   - *c.* *Euglena viridis*, with complete nucleus in early stage of division.
   - *d.* *Euglena viridis*, with nucleus in anaphase of division.

9. PREPARATIONS ILLUSTRATING THE DEVELOPMENT OF SPERMATOZOA IN THE HEMIPTERA. Exhibited by F. C. Paulmier.

10. PREPARATIONS ILLUSTRATING THE DEVELOPMENT OF THE SPERMATOZOA IN AMPHIBIA. Exhibited by J. H. McGregor.

11. PREPARATION SHOWING ALVEOLAR STRUCTURE OF PROTOPLASM IN THE EGG. Exhibited by Prof. E. B. Wilson.

12. SERIAL SECTIONS OF THE HEAD OF YOUNG DOG-FISH (*Squalus acanthias*). Prepared for the study of the Cranial Nerves. Exhibited by Dr. O. S. Strong.

13. SECTIONS OF GROWING EGGS OF AN ASCIDIAN, *Molgula manhattensis*, Illustrating the Formation of the Albuminous Food-material or Yolk. Exhibited by H. E. Crampton, Jr.

14. PECULIAR STAGES IN THE MATURATION AND FERTILIZATION OF THE EGG OF AN ASCIDIAN, *Molgula manhattensis*. Exhibited by H. E. Crampton, Jr.

15. EXHIBIT OF CYTOLOGICAL PREPARATIONS, by Francis B. Sumner.
    - *a*. Fertilization stage of *Fundulus heteroclitus*. Entrance of spermatozoön.
    - *b*. Abnormal amphiaster in periblast of *Amiurus*. A nuclear division with no nucleus present.
    - *c*. Degenerate mitoses. Transition to amitosis.

16. MAPS AND DESIGNS OF BUILDINGS OF NEW YORK ZOOLOGICAL SOCIETY. Exhibited by Prof. H. F. Osborn and W. T. Hornaday.

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INDEX SLIPS.

These index slips are furnished for two purposes:

1. To furnish the materials for a catalogue, the entries being cut out and pasted on cards.

2. To form the basis of both the index of the Annals of the New York Academy of Sciences and of a subject-catalogue.

Under the author's name is given the full title and reference. Then follow cross references to the important topics discussed. Minor references are limited to additions to scientific knowledge.

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